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CITRUS AND SUBTROPICAL FRUIT RESEARCH

of the

United States Department of Agriculture
and Cooperating Agencies

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having an interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the past year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, Agricultural Marketing, and The Farm Index.

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GRU... RECORDS

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ADVISORY COMMITTEES

The research program of the Department of Agriculture is reviewed annually by the following advisory committees:

1. Farm Resources and Facilities Research
2. Utilization Research and Development
3. Human Nutrition and Consumer Use Research
4. Marketing Research
5. Agricultural Economics Research
6. Forestry Research
7. Animal and Animal Products Research
8. Cotton Research
9. Grain and Forage Crops Research
10. Horticultural Crops Research
11. Oilseed, Peanut and Sugar Crops Research
12. Plant Science and Entomology Research
13. Tobacco Research

ORGANIZATIONAL UNIT PROGRESS REPORTS

The source materials used by the advisory committees are of two types. First there are Organizational Unit Reports that cover the work of the Divisions or Services listed below. The number prefixes refer to advisory committees listed above that review all of the work of the respective Divisions or Services.

Agricultural Research Service (ARS)

- 1 - Agricultural Engineering
- 1 - Soil and Water Conservation
- 2 - Utilization -- Eastern
- 2 - Utilization -- Northern
- 2 - Utilization -- Southern
- 2 - Utilization -- Western
- 3 - Human Nutrition
- 3 - Clothing and Housing
- 3 - Consumer and Food Economics
- 4 - Market Quality
- 4 - Transportation and Facilities
- 7 - Animal Husbandry
- 7 - Animal Disease and Parasite
- 12 - Crops
- 12 - Entomology

Economic Research Service (ERS)

- 1, 5 - Resource Development Economics
- 4, 5 - Marketing Economics
- 5 - Farm Production Economics
- 5 - Economic and Statistical Analysis
- 5 - Foreign Development and Trade Analysis
- 5 - Foreign Analysis Division

Forest Service - Research (FS)

- 6 - Forest Economics and Marketing
- 6 - Forest Products and Engineering
- 6 - Forest Protection
- 6 - Timber Management
- 6 - Watershed, Recreation and Range

Other Services

- 4, 5 - Farmer Cooperative Service (FCS)
- 4, 5 - Statistical Reporting Service(SRS)

SUBJECT MATTER PROGRESS REPORTS

The second type of report brings together the USDA program and progress for the following commodities and subjects:

- | | |
|--|--------------------------------------|
| 3 - Rural Dwellings | 8 - Cotton and Cottonseed |
| 6 - Forestry (Other than Forest Service) | 9 - Grain and Forage Crops |
| 7 - Beef Cattle | 10 - Citrus and Subtropical Fruit |
| 7 - Dairy | 10 - Deciduous Fruit and Tree Nut |
| 7 - Poultry | 10 - Potato |
| 7 - Sheep and Wool | 10 - Vegetable |
| 7 - Swine | 10 - Florist, Nursery and Shade Tree |
| 7 - Cross Species and Miscellaneous | 11 - Oilseeds and Peanut |
| Animal Research | 11 - Sugar |
| | 13 - Tobacco |

A copy of any of the reports may be requested from Barnard Joy, Research Program Development and Evaluation Staff, U. S. Department of Agriculture, Washington, D. C. 20250

INTRODUCTION

This report deals with research on citrus and subtropical fruits such as orange, grapefruit, lemon, avocado, mango, papaya, lychee and dates. It does not include extensive cross commodity work, much of it basic in character, which contributes to the solution of problems of other commodities, as well as those of citrus and subtropical fruits. The progress on cross commodity work is found in the organizational unit reports of the several research divisions of the Department.

This report is organized by problem areas which are shown as the major subjects under the three main divisions in the table of contents. For each of the problem areas there is a statement of (1) Problem, (2) USDA AND COOPERATIVE PROGRAM, (3) PROGRAM OF STATE EXPERIMENT STATIONS, (4) PROGRESS--USDA AND COOPERATIVE PROGRAMS, (5) PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS.

Research on citrus and subtropical fruit is supported by (1) Federal funds appropriated to the research agencies of the USDA, (2) Federal and State funds appropriated to the research agencies of the USDA, and (3) private funds for research carried on in private laboratories or for support of State Station or USDA work.

Research by USDA

Farm Research is conducted by the Crops, Entomology, and Agricultural Engineering Divisions of the Agricultural Research Service. It comprises investigations on introduction, breeding and genetics, variety evaluation, culture, diseases, nematodes, weed control, insect control and crop harvesting and handling operations and equipment.

Nutrition, Consumer and Industrial Use Research is conducted by the Human Nutrition, Consumer and Food Economics, and the Southern and Western Utilization Research and Development Divisions of ARS. Nutrition and consumer use pertains to composition and nutritive value; physiological availability of nutrients and their effects; and new and improved methods of preparation, preservation and care in homes, eating establishments and institutions; the nutritional appraisal of diets and food supplies; and surveys of the kinds, amounts and costs of foods consumed by different population groups and the practices of families in the purchase and household use of various foods. Utilization research and development deals with methods of preservation through canning, drying, freezing, or combinations of these methods, and also with the origination of new forms of food products or combinations of citrus and subtropical fruits with other foods.

Marketing and Economic Research is conducted by the Market Quality and the Transportation and Facilities Research Divisions, Agricultural Research Service, by the Economic Research Service, the Farmers Cooperative Service, and the Statistical Reporting Service. The physical, biological, and economic aspects of assembly, packaging, transporting, storing, and distribution from the time the product leaves the farm until it reaches the

ultimate consumer are investigated by the Market Quality and Transportation and Facility Research Divisions of ARS. Economic research is concerned with merchandising and promotion; economics of transportation, economics of product quality; market structure, practices and competition; information, outlook and rural development; marketing costs, margins and efficiency; market potentials; supply, demand and price; outlook and situation; improving marketing of farmer cooperatives; and consumer preference and quality discrimination. It is carried on by the Marketing Economics and Economic and Statistical Analysis Divisions of ERS, the Marketing Division of FCS, and the Standards and Research Division of SRS.

Interrelationships Among Department, State and Private Research

Much of the Department's research is cooperative with State Experiment Stations, various sectors of industry and with growers. Cooperative work is jointly planned and frequently participated in by Federal, State and industry workers. The nature of the cooperation varies with each study. It is developed to fully utilize the personnel and other resources of the co-operators. There is regular exchange of information between State and Department scientists to assure that the research programs complement each other and eliminate undesirable duplication. Many Department employees are located at State Stations and use laboratories and office space close to, or furnished by, the State.

Privately supported research of considerable extent is done by food processors and distributors, food industry and trade associations, food container and equipment suppliers, marketing equipment and facility manufacturers, chemical and fertilizer companies, package and container manufacturers, market research institutes and corporations, nurserymen, orchardists, and grove owners. Industry's cooperation in supporting research on citrus and subtropical fruits in the form of grants, gifts or loans of materials, equipment and facilities at Federal and State stations has contributed greatly to its success.

A number of food processing companies and wholesale and retail distributors are presently conducting research in various phases of products and process development in frozen, canned, and dried citrus and subtropical fruit products. The canning, freezing and dehydrating industries each maintain an association with a technical staff and either do research in their own laboratories or support research at USDA laboratories, universities, and other organizations. Allied industries and suppliers to the food processing industry maintain excellent laboratories and large research staffs to provide technical information to the industry.

INTRODUCTION (Cont.)

Marketing equipment and facility manufacturers also make sizeable contributions to research on the development of equipment for handling fruits on the farm or orchard, into and out of packing houses, transportation vehicle, wholesale distribution center and in the retail establishment, as well as research on the containers in which it is moved and on the transportation vehicles from which it moves from one point in the distribution channel to another. Market research institutes and others in marketing economics research are largely concerned with research in consumer preference, market potentials, market promotion and development, and interregional and inter-market competition

Chemical and fertilizer companies are significant factors in research on the development of new materials or combinations of materials to produce more efficiently, high quality fruits through better nutrition of the growing plant, control of diseases, insects, nematodes, weeds and the regulation of growth processes through use of growth regulator substances such as fruit set thinners, stop-drop chemicals, bloom retarders, etc.

A number of the larger nurserymen spend considerable time and money in the search for, and testing of, new varieties of citrus and subtropical fruits in the major production areas; sometimes on their own acreage, but usually in cooperation with some grower. The contribution of growers to our overall research effort on citrus and subtropical fruits is substantial. Certainly, in the field of production his help is indispensable for most of the laboratory research results must finally be confirmed by orchard scale experiments. The grower cooperates with the USDA, State Experiment Stations and suppliers of many materials and equipment--usually, without compensation except for the experience and knowledge gained. Citrus growers in Arizona, California, Florida and Texas are conducting research in such areas as flat land reclamation, cultural practices, fertilization, tree spacing, hedging, rootstock evaluation, clonal studies, and are actively cooperating the Department and State Experiment Stations by propagating and testing seedlings, crosses and new varieties.

Examples of Recent Research Accomplishments by USDA and Cooperating Scientists

New Citrus Varieties Introduced. Four new citrus varieties -- Page orange and Fairchild, Fortune, and Fremont tangerines -- have been introduced. Page orange, designated as an orange because of its round shape, was selected because of its attractive color, excellent quality, and early season of maturity. It has been most widely tested in Florida where it should be valuable in the early season fresh-fruit trade. Fairchild, Fremont, and Fortune tangerines are hybrids of Clementine tangerine with Orlando tangelo, Ponkan and Dancy tangerines, respectively. They carry the high quality of the Clementine and unite it with desirable features of the other parents to provide new fruits, particularly suited to the hot desert valleys of California. Fairchild, named after the great plant

explorer, David Fairchild, was selected because it matures earlier, is more attractive in appearance, and less subject to granulation, than Clementine. Fremont, named after John Fremont, earlier explorer of western United States, was selected because of its high quality and excellent appearance, maturing in midseason between Clementine and Dancy. Fortune, named after Robert Fortune, English explorer in China and introducer of the kumquat, was selected as a late maturing, high quality tangerine. Although fruit matures in January at Indio, it can be held on the trees in good condition through March.

Releases of sterile Mexican fruit flies eliminate need for insecticide spray. Applications of bait sprays have been relied on since 1955 to suppress the Mexican fruit fly in Northwestern Mexico, where it periodically appears when infested fruits are brought in from further south. Protective sprays have also been applied to certain threatened areas along the border in California. Weekly releases of thousands of sterile male fruit flies to mate with wild female flies, thereby preventing fertilization and establishment of infestations, eliminated the need for the costly and annoying spray programs previously conducted in northern Baja California and southern California. The released flies were produced and sterilized with tepa at the Mexico City laboratory where special techniques were developed for mass rearing, sterilization, and transportation. They were shipped by air to Los Angeles for distribution in Baja California by the Plant Pest Control Division in cooperation with the Mexican Direccion de Defensa Agricola. This was the first practical use of sterilized insects to prevent establishment of introduced pests.

Significant advance in the potential use of insect chemosterilants. Hexamethylphosphoramide (hempa) and hexamethylmelamine (hemel), dimethylamido analogs of tepa and tretamine but much lower in mammalian toxicity were effective in laboratory tests in sterilizing males of several species of insects including the house fly, mosquitoes, Mexican fruit fly, screw-worm fly, boll weevil, and codling moth. Progress in development of the chemosterilant approach to insect control has been retarded by the high mammalian toxicity of formerly available materials. This discovery of less hazardous compounds may permit earlier application of sterilization control to specific insect problems.

Flavoring Constituent Identified in Grapefruit. Department scientists have discovered the identity of a constituent, nootkatone, in the essential oil of desert grapefruit which appears to be characteristic of the fresh fruit aroma. Nootkatone is present in good quality grapefruit oil to the extent of 0.3%, whereas poorer quality oils contain lesser amounts. It is present in small amounts in certain other citrus oils such as bergamot, lemon, lime, orange and tangerine. There are several potential applications of this discovery: (1) the nootkatone content of grapefruit oil may be used as an objective measure of its flavor quality; (2) addition of nootkatone to grapefruit products should prove to be a simple way to intensify the desired grapefruit aroma. Horticulturists and plant breeders should be able to use the nootkatone content to assess the value of new cultural practices and breeding studies on grapefruit flavor.

Heat Treatment for Control of Decay of Fresh Fruits and Vegetables. Although heat has been used to a limited extent to control certain plant diseases for many years, the recent concern regarding chemicals in foods has stimulated research with heat as a method of decay control. Following promising results obtained by the Department with hot water treatment of peaches (published in MRR 643) one large peach grower in Georgia successfully treated his entire crop in 1964. A very large packing house in South Carolina has also installed a heat-treating tank in the packing line. There is also a successful commercial application in Florida of the hot water treatment for the control of anthracnose decay of mangos. Promising results are being obtained experimentally with hot water for control of decay of bell peppers and citrus fruits and with hot air for control of decays of strawberries, red raspberries, and blueberries.

Irradiation. Placement of a mobile gamma irradiator at the Fresno field laboratory during the past fiscal year enabled evaluation of this treatment for a wide range of horticultural crops, field crops, meats, poultry, and stored product insects under semi-commercial conditions. Postharvest decay reduction, without serious adverse effects on the quality of the commodity, was obtained with fresh strawberries, nectarines, figs, and mushrooms. Most of the other horticultural commodities treated showed adverse effects on texture, color, or flavor at irradiation dosages producing worthwhile decay reduction. With this information producers and shippers of horticultural crops can better assess the commercial possibilities of the irradiation treatment.

Development of Design for Multi-Purpose Van Container. A design for a multi-purpose van container for transporting farm and food products has been developed. When completed, the van can haul frozen and nonfrozen products as well as dry cargo. It can be moved by highway, rail, water, and possibly air. When widely adopted, and industry interest indicates it will be, the van container will bring significant reduction in the annual bill for transporting agricultural products and supplies, and at the same time furnish better protection to products which require special environment during transit.

8. Highway Transportation of Farm Products. -- Motortruck transportation of unmanufactured farm products continues to be an area where not enough is known about the quantities moved by these carriers and about the charges made by them for their services. The data gap exists because interstate hauling of these commodities is "exempt" from Government regulation insofar as rates charged and routes traveled are concerned. This year some research has been completed in this area and some has been initiated.

A study of the operating practices and nature of competition among truckers engaged primarily in hauling unmanufactured farm products for-hire was completed and the results were published. The findings analyzed methods used by these carriers to obtain business, competitive relationships, operating costs, and the practice of trip-leasing of equipment.

7. Promotional Expenditures by Producer Organizations. -- A survey of promotional expenditures of producer organizations and similar agriculturally oriented groups indicates that there are almost 1,200 of these organizations spending a total of about \$86 million annually for the promotion of agricultural products. This is an increase of nearly \$20 million over expenditures shown by these organizations in a similar survey in 1958. This increase in expenditures represents added self-help efforts by producer groups to build and strengthen markets for their products and to combat the problem of an imbalance between demand and supply. Fruit, which was the leading product promoted, and dairy, which ranked second, accounted for well over 50 percent of these expenditures. Meat and livestock products ranked third with expenditures of over \$6 million per year. Promotional expenditures for natural fibers, poultry and eggs, and field crops were comparable ranging between \$4 and \$5 million per year for each commodity class.

Voluntary producer-processor groups spent more than any of the other groups, with expenditures of nearly \$32 million per year. Cooperatives and commissions and boards operating under enabling legislation were also important, with each type of organization spending about \$25 million per year. State Departments of Agriculture and other organizations not identified spent less than the other types of organizations, with expenditures in each of these categories averaging about \$1.5 million per year.

I. FARM RESEARCH

CROP INTRODUCTION AND EVALUATION
Crops Research Division, ARS

Problem. American agriculture is based on the expanding culture of crops most of which have originated outside our continental limits. The improvement of existing crop varieties, the selection of new lines with natural resistance to insects and diseases, and the development of any number of important characteristics is dependent on a continuous flow of introduced germ plasm. Inherent in this is the preliminary evaluation and cataloging of plant introductions for traits which will be of use to plant breeders and the agronomic development of potential crops as a result of joint botanical-utilization screening research on new crops. These demands require the search for and introduction of 8 to 10 thousand plant collections and samples for analysis yearly.

USDA AND COOPERATIVE PROGRAM

The nature of this program is to conduct investigations concerned with the introduction, evaluation, and maintenance of plant germ plasm for the development of a strong yet diversified agricultural program for the United States. Research involves a continuing assessment of the world's plant resources; procurement of stocks through exploration and international exchange; the evaluation of the introductions either as breeding stocks, as potential new crops, or for land reclamation and conservation purposes, through a national cooperative research effort, and the preservation of these materials either as seed or as vegetative stocks. Leadership for this program is at Beltsville, Maryland.

Four national introduction stations are responsible for evaluation, maintenance, and/or quarantine of new introductions which require special handling: Chico, California; Miami, Florida; Savannah, Georgia; and Glenn Dale, Maryland. The responsibility for preservation of seed stocks of national interest lies with the National Seed Storage Laboratory, Fort Collins, Colorado. Cooperative new crops studies to determine significant agronomic characteristics of plants having valuable end-products are conducted cooperatively with experiment stations of Alabama, Montana, Nebraska, North Carolina, South Carolina, and Texas. Four regional and one inter-regional introduction stations deal with the evaluation of crop breeding stocks essential to programs in state experiment stations.

Ten P.L. 480 projects are currently active, all having to do with the collection and screening of native plants of potential use in the agriculture of the United States. These countries and grant amounts are as follows: Colombia (S5-CR-1) - \$113,159; India (A7-CR-52) - \$20,752; Israel (A10-CR-10) - \$115,555; Israel (A10-CR-11) - \$87,337; Korea (A13-CR-1) - \$46,692; Pakistan (A17-CR-5) - \$60,449; Spain (E25-CR-11) - \$156,583; Turkey (A22-CR-1) - \$134,444; Uruguay (S9-CR-3) - \$114,024; Yugoslavia (E30-CR-2) - \$30,000.

The Federal scientific effort devoted to research in New Crops totals 38.5 man-years. Of this number, 3.0 are devoted to international plant exchange, 3.2 to botanical investigations, 6.2 to special plant procurement and botanical activities. Research on new crop evaluation includes 8.7 man-years for horticultural research, 3.8 for agronomic studies, 6.1 devoted to evaluation of potential new crops, 4.0 to pathology, and 3.5 to maintenance of germ plasm.

PROGRAM OF STATE EXPERIMENT STATIONS

While responsibility for collecting and introducing plant material into this country rests predominantly with the Department, the State stations cooperate actively in the preservation, multiplication, and preliminary evaluation of such materials and in domestic and other explorations for the introduction of new materials. An elaborate system supported in part by the States and in part by the Department has been organized for the purpose of placing introduced materials in the hands of interested plant researchers throughout the country. This system consists of a series of 5 plant introduction stations located respectively in Geneva, New York; Experiment, Georgia; Ames, Iowa; Pullman, Washington; and Sturgeon Bay, Wisconsin. Research of the State stations is organized and coordinated through 4 regional projects and 1 inter-regional project: NE-9, Discovery and Preservation of Valuable Plant Germ Plasm; S-9, The Introduction, Multiplication, and Evaluation of New Plants for Industrial and Agricultural Use and the Preservation of Valuable Germ Plasm; NC-7, New Plants - for Industrial and Agricultural Utilization; W-6, The Introduction, Multiplication, Preservation, and Determination of the Value of New Plants for Industrial and Other Purposes; and IR-1, Introduction, Preservation, Classification, Distribution, and Preliminary Evaluation of Wild and Cultivated Species of Solanum. All 50 States and Puerto Rico cooperate in this research. Cooperation between the State stations and the Department in this program is outstanding and of great mutual benefit.

The total research effort on replacement crop introduction and evaluation at the State stations is approximately 60.0 professional man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

From a seedling population of 'Arue' avocado which has come into bearing at Miami, Florida, one seedling compares well with mid-season varieties grown commercially and will be evaluated further for production and quality.

Hardiness studies on lychee at Miami, Florida, and observations on damage as a result of the severe 1962-63 freeze, show that this crop will be restricted in range to about that of the Mexican avocado and Persian lime. Storage studies on lychee in relation to retention of fruit color, flavor, and keeping quality showed P.I. 51471 is conclusively superior to all other introductions when stored at 10°C. and may prove to be an excellent variety for shipping purposes.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

- Gaskins, M. H. and H. F. Winters. 1962. Herbicide trials with young tropical and subtropical fruit and nut trees. Proc. Fla. State Hort. Soc. 75: 418-420.
- Knight, R. J. and H. F. Winters. 1962. Pollination and fruit set of yellow passionfruit in southern Florida. Proc. Fla. State Hort. Soc. 75: 412-418.
- Winters, H. F. 1963. The Natal plum. Amer. Hort. Mag. 42(2):92-95.

CULTURE, BREEDING AND GENETICS,
DISEASE INVESTIGATIONS AND VARIETY EVALUATION
Crops Research Division, ARS

Problem. To maintain the position of prominence citrus holds in the health and diet of Americans, more information is needed on the factors which influence successful and economic production. More precise information is needed on the interrelation between climatic factors and growth, cold hardiness and production; on the absorption processes and functions of various elements needed in growth and the effects of soil salinity, alkalinity and high water retention on growth; on the biochemistry of citrus metabolism and the effects of air pollutants on metabolism and growth; on various diseases and methods to control them. New rootstocks are needed which induce more cold hardiness in tops, are disease and nematode tolerant, tolerant to high soil alkalinity, salinity, poor drainage and which induce high yields of high quality fruit. New top varieties are needed with greater cold hardiness, greater disease resistance, better fruit quality, a widespread in season of maturity, suitable both for fresh market and processing.

The United States has a humid subtropical zone extending from Charlestown, S.C., southward to the Florida Keys and westward to Corpus Christi, Texas, to which some varieties and kinds of subtropical fruits are potentially adapted. Other such fruits may be adapted to the irrigated regions extending from Corpus Christi southward to Brownsville and throughout the Lower Rio Grande Valley of Texas. Information is needed about the adaptation and culture of many tropical fruit plants which, in addition to their value as home fruit garden plants, may have commercial possibilities.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term research program involving plant pathologists, physiologists, horticulturists, and plant breeders carrying on both basic and applied studies to enable growers of dates, avocados, and citrus to increase both production and quality. Federal stations having citrus and subtropical fruit research are Orlando, Florida; Weslaco, Texas; and Indio and Brawley, California. Date breeding, disease, and cultural research is done at Indio. Avocado disease and cultural research is done at Weslaco. Citrus research is done at the three Federal stations. Citrus hybridizations are made at Orlando and Indio but not at Weslaco and progenies are evaluated at all three locations; disease studies are carried on at all three Federal stations; basic physiology studies of cold hardiness are centered at Weslaco, with variety and hybrid progenies evaluated for cold hardiness at all three stations; rootstock evaluation on a field basis is centered in Florida but preliminary evaluation of hybrid rootstock progenies and certain species for cold hardiness, salt tolerance, and disease resistance is carried on at all three stations; basic nutrition is carried on principally in Florida but some work is also done in Texas and California. Climatology is carried on in Florida, Texas, Arizona, and in several

locations in California; the work in Arizona and California is in cooperation with the Agricultural Experiment Stations. Air pollution studies are carried on in California under contract with the University of California at Riverside.

The Federal scientific effort devoted to research in this area totals 17 man-years. Of this number 3.5 is devoted to breeding, 5.5 to diseases, 0.5 to variety evaluation, and 7.5 to culture.

Five 5-year PL 480 projects are currently in effect: (1) with the Instituto Biologica, Sao Paulo, Brazil, for studies on interference between strains of the tristeza virus (S3-CR-2) providing funds with an \$85,156 equivalent of Brazilian cruzieros and having a projected duration from 1961 to 1966; (2) with the Israel Ministry of Agriculture for studies on the physiological basis of tolerance of evergreen fruit trees to lime and saline soil and water conditions with special reference to the selection of rootstocks of avocado and citrus by physiological tests (A10-CR-7) providing funds with a \$118,772 equivalent of Israeli pounds and having a projected duration from 1960 to 1965; (3) with the Israel Ministry of Agriculture, Rehovot, Israel, for studies of new methods for assessing nutrient status in citrus trees and other plants (A10-CR-36) providing funds with a \$68,900 equivalent in Israeli pounds and having a projected duration from 1963 to 1968; (4) with the Indian Agricultural Research Institute, New Delhi, for studies on citrus dieback in India (A7-CR-3) providing funds with a \$107,432 equivalent in Indian rupees and having a projected duration from 1961 to 1966; and (5) with the Plant Virus Research Laboratory, Ministry of Agriculture, Cairo, Egypt, for citrus virus research (F4-CR-2) with funds providing a \$34,236 equivalent of Egyptian pounds and with a projected duration from 1963 to 1968.

PROGRAM OF STATE EXPERIMENT STATIONS

Six states and Puerto Rico have research on citrus and subtropical fruit. Cultural research on citrus includes investigations of rootstock and rootstock-scion relationships, response of citrus to spacing and pruning, response of citrus to soil management practices and irrigation, mineral nutrition, protecting citrus from cold injury and determining the effects of salinity on citrus behavior. Other tropical and subtropical fruits receiving cultural research are avocados, pineapples, coffee, olives, figs, papayas, passion fruit, mangoes, and guava.

Citrus breeding or variety evaluation research is in progress in California, Florida, and Texas. Avocado breeding is in progress in California, Florida, and Puerto Rico. Texas and Louisiana are undertaking fig breeding or variety evaluation. Breeding of papayas, coffee, lychee, mango, guava, pineapple, and tea is being carried in at least one or more locations.

Research on diseases of citrus is in progress in all States where this crop is grown. In three institutions there is emphasis on the virus diseases of

citrus. Leadership in this research is providing new knowledge on the detection, identification, and transmission of citrus viruses. Fundamental research on the nature of specific viruses, on virus synthesis and multiplication, and on the mechanism of resistance is contributing new scientific knowledge. Through several projects, station scientists are learning more of the role of nematodes in citrus culture. Through basic studies on these nemas, specialized and highly effective methods of control, including biological, physical, and chemical are being developed. A number of nema problems are associated with other disease complexes in citrus, such as root rots. Fungus and bacterial diseases including fruit rots, wood necrosis and root rots are being emphasized in the research of these scientists.

Diseases of avocado, pineapple, banana, coffee, dates, and palm nuts are also being studied at the stations. Bacterial and nematode diseases, re-plant problems, and fruit rots are of primary concern.

The total research effort on citrus and subtropical fruits at 6 States and Puerto Rico is approximately 17.0 professional man-years, of which 6.6 is for culture, 4.2 for breeding and variety evaluation, and 6.2 for disease investigations.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Breeding

1. Citrus.

a. Orange. In Florida, a Clementine tangerine X Minneola tangelo hybrid (Orlando. No. 421-17-8) was introduced by the Department and named PAGE. The fruit resembles a medium size round orange and is therefore classed as an orange instead of a tangerine hybrid. It ripens in October and reaches its prime in November. The flavor is excellent, rich, and sweet. Solids reach 12 to 13 percent in November with 1 percent acids. Flesh color is dark orange. The fruit can be peeled easily and the rind color is deep orange to scarlet. Trees are moderately vigorous, nearly thornless with upright branches spreading under a heavy fruit load. PAGE is introduced because of its attractive color, excellent fruit quality, and early season of maturity. It will have higher quality if grown on sweet orange or sour orange rootstocks; trees on Rough lemon are vigorous but the fruit tends to be low in solids and volume of juice.

b. Tangerine. At Indio, California, three tangerine hybrids were introduced by the Department and named FAIRCHILD, FREMONT, and FORTUNE respectively. FAIRCHILD (Indio No. C48-14-39) originated from a cross of Clementine tangerine X Orlando tangelo. Though the pollen parent of Fairchild is a tangelo, neither tree nor fruit shows obvious evidence of being derived in part from the grapefruit, but shows the typical characteristics of the tangerine, consequently Fairchild is classed as a tangerine. The fruit is of

medium size, oblate, with a smooth, deep orange colored peel that is easily removed. It ripens in early November and retains good quality through December. The flavor is pleasant, rich, and sweet. The flesh is orange colored, firm but tender and juicy. The trees are vigorous, productive, and nearly thornless with a dense, spreading top. Fairchild ripens at the same time as Clementine but its fruits usually complete the color change from green to orange earlier and consequently in some seasons may be harvested earlier than Clementine. Fairchild is introduced because it is as early as Clementine and the fruits are more uniform and attractive and less subject to granulation.

FREMONT (Indio No. C54-3-1) originated from a cross of Clementine X Ponkan tangerines. The fruit is of medium size, oblate, and has a smooth, bright reddish orange peel that is easy to remove. It is early ripening, being ready to harvest just after Clementine and ahead of Dancy. The flavor is excellent, sprightly, acid yet sweet, and good quality is retained even when the fruit is overripe in January or later. The flesh is deep orange in color, tender and juicy. Trees are moderately vigorous, precocious, productive, and nearly thornless with upright branches spreading under a heavy fruit load. Fremont is introduced because of its excellent fruit quality and appearance and freedom of fruit from granulation even when grown on Rough lemon rootstock on light sandy soils.

FORTUNE (Indio No. C48-9-6) originated from a cross of Clementine X Dancy tangerines. Fortune fruit is medium to large in size, oblate, with a slightly bumpy orange to reddish-orange peel that is close fitting but fairly easy to remove. It is late ripening, the harvest season being late January through March. The flavor is sub-acid, sprightly and pleasing. The flesh is orange colored, firm but tender and juicy. Fortune is vigorous and productive. The top, spreading and dense, forms a leafy canopy over most of the fruit and protects it from sunburn and frost. The quality of Fortune fruit is satisfactory on trees on Rough lemon rootstock but for highest quality and late holding on the tree, sour orange, Cleopatra mandarin or Troyer citrange rootstock is recommended. Fortune is introduced because of its attractive, high quality fruit and late maturity season. Fruit, mature in late January, may be held on the tree in good condition through March, a month or more beyond the normal tangerine season in the Coachella Valley.

B. Diseases

1. Citrus

a. Virus diseases. Tristeza disease of citrus continues to be a perplexing problem in Florida. Approximately 30 percent of the State's orange planting is on tristeza-susceptible sour orange rootstock and this rootstock continues to be used in large amounts in new plantings. Indexing tests using "Mexican" lime plants as indicators, show that the virus is

quite widespread in the State's citrus plantings yet serious tree decline has occurred only in limited areas for reasons not yet clearly understood. The practical solution to the tristeza problem rests in finding an acceptable tristeza tolerant rootstock substitute for sour orange. Citrus seedlings have been successfully approach-grafted to the herbaceous annual Gomphrena globosa (amaranth) and this may be a valuable tool to index for citrus viruses.

Research on tristeza is sponsored by the United States in Brazil under provisions of PL 480 project S3-CR-2 entitled "Studies on interference between strains of the tristeza virus." Tristeza strains have been isolated which fall into one of two classes: (1) those which produce mild symptoms, and (2) those which produce stem pitting on Pera sweet orange and Galego lime. The type of stem pitting in Brazil is of world concern since it causes serious damage to Pera sweet orange regardless of rootstock.

University of California and Arizona pathologists have developed a rapid index test for exocortis virus using Etrog citron provided by the Department as the test plant. This discovery promises to shorten the time to determine the presence of exocortis from 6 years to 6 weeks and to expedite the budwood certification programs.

b. Fungus diseases.

The Phytophthora root rot work at Orlando has been directed towards the development of an improved technique for screening citrus varieties for tolerance to P. parasitica. The present methods do not detect degrees of Phytophthora tolerance such as that manifested by sour orange stock, the stock most commonly used for foot rot tolerance. Phytophthora tolerance is one of the major considerations in the search for an ideal rootstock. Studies showed that the fungus can be latent in the bark of stems and roots without production of foot rot symptoms; and that the relative pathogenicity of a given P. parasitica isolate remains stable for at least 4 years.

Thielaviopsis basicola has been found to attack the roots of a number of citrus varieties in laboratory tests. Injury is severe and pathogenicity of the strain has been proven. T. basicola has been isolated from a number of citrus groves in Florida and may be the cause of tree losses as well as a threat to the replanting of groves. The Florida isolate of T. basicola is pathogenic to all nematode-tolerant rootstocks tested as well as to a number of commercial rootstock varieties. This is the first time that this fungus has been reported from Florida citrus orchards.

c. Citrus diseases of undetermined cause. A serious dieback of the newly released Robinson tangerine has killed a large number of young trees. Diplodia fungus appears to be involved. Isolation of this fungus and its re-inoculation into clean Robinson cuttings have produced symptoms typical of dieback in the field.

d. Biological control of citrus nematodes. Rootstocks tolerant to spreading decline. The Department, in cooperation with the Florida Agricultural Experiment Station, introduced three nematode-resistant citrus rootstocks and named them ESTES lemon, MILAM lemon, and RIDGE PINEAPPLE sweet orange, respectively.

ESTES lemon, tested as rough lemon-B, was originated by forcing shoots from the rootstock of a vigorous Valencia orange tree growing in a burrowing nematode-infested grove. The Valencia tree on the parent rootstock has consistently yielded three to five times as much fruit as surrounding trees on ordinary rough lemon infested rootstocks. Estes was only slightly dwarfed when grown as rooted cuttings in burrowing nematode-infested soil in the greenhouse even though some nematodes continued to live in the roots. Estes cannot be visually distinguished from other rough lemon clones in Florida.

MILAM lemon, tested as Clone-X, originated from the rootstock of a vigorous healthy appearing Parson Brown tree growing in a grove severely affected with spreading decline and was first noted in 1954. Shoots from the rootstock were propagated and the fruit borne on Milam trees indicated that it is possibly a hybrid rough lemon with an unknown pollen parent. Seedlings derived from these fruit and cuttings taken from the original root sprouts grown in soil heavily infested with burrowing nematodes have equalled the growth of sister seedlings and cuttings growing in non-infested soil. Nematodes initially penetrated the roots but were gone 9 months later.

RIDGE PINEAPPLE sweet orange, tested as pineapple-156, is a single tree in the U. S. Department of Agriculture collection at Orlovista, Florida. It does not differ in fruit or foliage characters from ordinary pineapple but the origin is unknown. Seedlings from this tree grown in soil heavily infested with burrowing nematodes have equalled the growth of sister seedlings growing in non-infested soil. Nematodes initially penetrated the roots but had disappeared after 9 months.

2. Dates

a. Root-knot nematodes are generally present on date palms in California's Coachella Valley. Severe nematode damage, particularly from Meliodgyne javanica, was done to germinating palm seedlings at the Indio date breeding garden in 1962.

C. Varietal Evaluation

1. Citrus

The severe freeze in January 1963 in Florida provided a test of the relative cold hardiness of the citrus kinds and varieties grown in that State. Evaluations continued during 1963 confirmed early estimates of the superior cold

tolerance of most tangerines and tangerine hybrids as compared with the sweet oranges. The Orlando, Robinson, Osceola, Lee, and Page showed superior cold tolerance. The Temple, however, showed severe freeze damage as did the Murcott orange and the Dancy tangerine.

D. Culture

1. Citrus

a. Rootstocks. Among a large number of rootstocks included in several test plantings in Florida with both orange and grapefruit scions, Rangpur lime has thus far proved outstanding in tree vigor and in quantity of fruit produced. In all cases, it is at least as vigorous and productive as Rough lemon and produces fruit of better quality than Rough lemon, although not equal to the quality on sour orange rootstock. Its superior performance is evident on both light and heavy soils. In comparative trials for water tolerance, it is outstanding. Because of these features, it is believed it will prove a desirable stock for the flatwoods soils which generally have a water drainage problem and are usually quite variable in fertility. Although Rangpur is susceptible to *Phytophthora*, it is tristeza tolerant. It has not been used commercially in the past due to its intolerance to the xyloporosis and exocortis viruses. With virus-free budwood, these diseases no longer constitute a barrier to its use.

One-year-old grapefruit trees on 23 rootstocks showed different degrees of lime-induced chlorosis when grown on a calcareous soil site in Texas. Rootstocks indicating some tolerance to calcareous soils in this test were Rough lemon, sour orange, C. tachibana, Yuzu, sweet lime, and Taiwanica, in descending order. Extremely sensitive were citranges, citrumelos, sweet oranges, and many tangerine types and hybrids.

Many 15-year-old Valencia trees on various stocks survived the January 1962 freeze in Texas and bore fruit in 1964. Best yields in 1964 were from Morton, Rusk, and Savage citranges, Changsha mandarin, Severinia buxifolia, and Poncirus trifoliata. Yields in general again reflected the degree of injury to trees during the 1962 freeze.

Yields of 5-year-old Dancy tangerine and Valencia orange trees in rootstock test plantings in the Coachella Valley were greatest on C. macrophylla stock and about one box per tree less on Rough lemon. Carrizo and Troyer citranges, Bessie sweet orange, Taiwanica and Brazilian sour orange were among the top third of the 15 to 25 stocks used in the experimental plantings. On a given rootstock, the yield of Dancy was nearly twice that of Valencia. Transpiration studies of scion varieties on various rootstocks showed that per unit of leaf area, the rootstock influenced the transpiration rate. The rate was highest on sweet orange rootstocks and, in descending order, on Cleopatra, sour orange and Rough lemon. Rhoplex, a

vinyl plastic, sprayed on the foliage, showed potential to decrease the transpiration rate in the orchard.

In studies on reciprocal effects of scion and rootstock technique was developed for a fairly simple and highly successful method of grafting young citrus fruits in the field from one tree to another so that they grow and develop to maturity on the nourishment of the foster mother tree. The technique is a useful one and is being used for studying translocation of materials from one variety of citrus tree to fruits of a diverse type of citrus. For example, this season ordinary varieties of fruits were grafted to trees of Poncirus trifoliata. The pungent, disagreeable constituents present in trifoliata were not translocated from the trifoliata tree to the grafted fruits, suggesting that these constituents are probably normally synthesized within the fruits themselves.

b. Mineral nutrition. Nitrogen. In Florida, nitrogen fertilizer studies continue to show that grapefruit requires less nitrogen than oranges. Nitrogen nutrition effects on freeze damage were noted during 1963. Grapefruit showed less defoliation after having received high, than low, nitrogen fertilization, and trees that received their nitrogen shortly before the freeze retained 50 percent more leaves than trees without nitrogen fertilization for almost a year previously.

Phosphorus. The 20-year phosphate-fertilizer experiment at Tavares, Florida, was terminated during 1963. In general, citrus derived no beneficial effects from applied phosphorus. The most notable results were (1) superphosphate applications reduce the feeder root density in the upper two feet of soil rather sharply, (2) virtually all of the phosphorus applied could be found in the top three feet of soil, (3) where no phosphorus was applied, that removed by the crops of oranges came from depths below two feet, (4) the phosphorus returned by normal leaf drop was more than sufficient to maintain the native level of phosphorus in the top two feet of soil, (5) the exchange capacity of the soil was unchanged over the two decades by either phosphorus accumulation or other cultural practice, and (6) the applied heavy metals - copper, zinc, and manganese - accumulated in the top six inches of soil independently of the phosphorus level.

Public Law 480 Research. "New methods for assessing nutrient status in citrus trees and other plants" is sponsored by the United States in Israel under provisions of A10-CR-36. Sensitive biochemical determinations of inorganic elements as well as biochemical and histochemical analyses of enzyme systems are being tested and developed. An early result indicates that iron deficiency causes a decrease in RNAase activity in lemon-leaf extracts.

c. Salt tolerance. Pot culture studies at Indio showed that the rate of chloride uptake by a known tolerant variety, Rangpur lime, was very slow when compared to chloride uptake by a sensitive variety, Rough lemon. This

difference can be detected as soon as one week after the start of salt applications. There was no difference in rate of chloride uptake or in levels of chloride attained in the plants when they were grown in solutions of sodium chloride, calcium chloride or mixtures of the salts at relatively high concentrations. This is in contrast to experiments from Texas in which more chloride accumulated in foliage of trees in sand and soil culture treated with CaCl_2 than with NaCl . In the cases of Rangpur lime and Cleopatra mandarin seedlings (salt-tolerant varieties), the larger the plant at the time of salt application, the less was the chloride uptake and the greater the percentage survival of the plants. There appears to be a good correlation between leaf chloride content and visual symptoms of salt injury.

At Weslaco, Texas, the salt tolerance tests of young Redblush grapefruit trees on sour orange rootstocks in soil and sand was terminated. Both salted and control trees grew better in sand than in loam in which growth was retarded by the salt treatments. NaCl and Na_2SO_4 additions to the loam depressed growth of trees more than CaCl_2 additions. More Cl accumulated in foliage of trees treated with CaCl_2 and less Na accumulated in those treated with Na_2SO_4 than in those treated with NaCl . Terminal, immature leaves contained more Cl than mature ones. The sodium content of leaves was considerably less from trees in loam than in sand, treated with NaCl or Na_2SO_4 . Trees receiving the Na_2SO_4 treatment accumulated more sulfates while those under other salt treatments depressed sulfate accumulation. Trees grown in loam contained more boron than trees in sand. Potassium was lower in foliage of trees grown in sand and a deficiency of K occurred in mature leaves of trees treated with NaCl and CaCl_2 and grown in sand. Chloride accumulation in all plant parts tested tended to be greater at warm and intermediate, than at cool, temperatures.

Public Law 480 Research. "The physiological basis of the tolerance of ever-green fruit trees to lime and saline soil and water conditions with special reference to the selection of rootstocks of avocado and citrus by physiological tests" is sponsored by the United States in Israel under the provisions of A10-CR-7. In avocado, lime tolerance is manifest in an inverse relationship between CO_2 dark fixation and levels of tannins and water soluble phenols. The uptake of sodium, promoted by RNAase available in the soil, can be suppressed somewhat by the addition of zinc. The uptake of sodium is accompanied by the uptake of potassium and decrease in the uptake of calcium and magnesium. The discovery the sodium uptake in citrus is passive and excretion is an active process, especially for Cleopatra mandarin, tends to indicate that ability to excrete is the mechanism of tolerance.

d. Tolerance of citrus to low temperatures. The influence of heaters, wind machines, and plastic covers on tree microclimate were studied during frost conditions when there was relatively little air movement. With temperature inversions at 40 feet around 70 degrees F., wind machines raised

air temperatures around trees from 1 to 7 degrees. Leaf temperatures remained similar to air temperature. In areas without wind machines, leaf temperatures subcooled 1 to 4 degrees below air temperature. Wind machines also reduced the amount of frost on the leaves and fruit. Heaters, placed 1 per 4 trees and burning at a low rate, did not influence air temperatures around the trees and consequently had no influence on frost formation.

Clean and white plastic covers over citrus trees resulted in colder air temperatures within the cover. Leaf temperatures were colder under the cover than outside. The addition of a small heat source under the cover raised air temperatures 5 to 10 degrees and with it raised leaf temperatures.

Controlled studies with young Redblush grapefruit trees to determine the basic factors of practical methods to promote cold hardiness in citrus showed that temperatures which induced bud dormancy resulted in decreased stem cambial activity and increased plant dormancy and cold hardiness. Slight decreases in total water content and freezing points and increases in total and reducing sugars of leaves accompanied increased plant leaf cold hardiness. Cold hardiness screening tests showed some citrus species, hybrids, and relatives to have high degrees of cold resistance.

An objective test for estimating the extent of freeze damage trees based upon color change of the dye tetrazolium red has been developed for citrus. The test does not indicate with certainty which tissues will ultimately die but the dye makes possible rapid current differentiation between dead and living cells. The dye test indicated that ray cells are more cold hardy than phloem cells.

e. Citrus climatology. Phenological stations were maintained at Orlando, and Clermont, Florida; Tempe, Arizona; and Indio, Riverside, and Santa Paula, California. Climatological data and phenological information from all stations were analyzed and processed under contract by the University of California.

During the period March 1, 1962 to February 28, 1963, spring flush and flowering began in February in Orlando, Clermont, Weslaco, and Indio, while that at Tempe, Riverside, and Santa Paula started approximately one month later. Extension growth of the spring flush was completed in late March at Orlando and Clermont, mid-April at Weslaco, mid-May at Tempe, Indio, and Riverside and mid-July at Santa Paula.

The fall flush ceased growth in early October at Tempe, early November at Indio and Riverside, and in mid-December at Orlando, Clermont, and Weslaco. Fruit growth terminated in early November at Tempe, Indio, and Riverside, and in mid-December at Orlando, Clermont, and Santa Paula. Radial growth of the trunk ceased in late October at Riverside, early December at Santa Paula, Indio, and Tempe and it continued to occur at a reduced rate all winter at Orlando, Clermont, and Weslaco.

At Weslaco, in carefully controlled temperature studies, grapefruit maturing on the tree in cool night and day temperatures had thicker and yellower rinds, higher juice solids and acid contents, but lower juice solid/acid ratios than those fruits maturing on trees at warm temperatures.

f. Biochemistry. In nutrient solution cultures tests on the effect of lead arsenate on citrus seedlings, it was found that the lead content of roots but not leaves increased as the lead content of nutrient solutions increased. Root growth was slightly stimulated by low levels of lead and inhibited by higher amounts. Shoot growth was not influenced except when the root system was poor, then shoot growth was inhibited. Lead has been shown to inhibit the dark fixation of CO_2 into organic acids and in the root tissues as lead increased the organic acid content decreased. However, the decrease of acid content on a weight basis may be because of the increase in corky tissue of the roots and not a change in the acid metabolism. Arsenic inhibited root growth and levels as low as 4 ppm killed sweet orange seedlings. Respiration of the leaves and transpiration were stimulated by small amounts of arsenic and inhibited by higher amounts up to 4 ppm.

2. Dates

a. Fruit thinning. Thinning Medjool dates by pollen dilution, with dead pollen, to 4 percent viability, resulted in rather erratic thinning but on the average was about as satisfactory with respect to fruit size and yield as hand thinning. Of six thinning chemicals used, each at four concentrations, only elgetol appeared to have any commercial adaptability. Elgetol produced good thinning on all three application dates over a wide range of concentration.

b. Bunch thinning. In 1963, all bunches were retained but strands or portions of bunches were removed or shortened so that fruit per bunch was systematically reduced to the range of 2500 to 1100 dates per bunch. As in previous years, the most profitable practice was that of less thinning because the premium for increased size did not nearly compensate for lowered yield.

c. Nitrogen fertilization. Application of as much as 8 pounds of nitrogen per mature Khadrawy palm per year for three years did not greatly affect the growth or yield of that variety.

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NEMATODE CONTROL

Crops Research Division, ARS

Problem. Plant-parasitic nematodes occur in all soils used for growing of crop plants and attack all kinds of plants grown for food, forage, fiber, feed, or ornamental purposes. It has been long known that severity of attack by certain fungi is greatly increased if nematodes are present; and nematodes have been known to be the vectors of several plant viruses. There is a need for improvements in the methods of controlling nematodes by crop rotations, cultural practices, chemicals and biological methods on citrus and subtropical fruits.

USDA AND COOPERATIVE PROGRAM

The Federal scientific effort devoted to research on nematode identification, physiology, and control was 19.0 professional man-years in F.Y. 1964, of which 1.7 was devoted to work on citrus fruits at Tempe, Ariz.; Orlando, Fla.; and Weslaco, Texas.

PROGRAM OF STATE EXPERIMENT STATIONS

Nematode investigations are being conducted at most of the State Stations, and many of these scientists participate in the four Regional Research Projects concerned with phytonematology. Through these and other projects at the various institutions scientists are contributing new knowledge on the genetics, physiology, and pathology of nemas. Some station scientists, as a result of their recent findings on nemas as vectors of viruses, are conducting intensive investigations of the biologies of this process. Other research on fundamental problems in nematology as well as work on identification and control are indicated in the appropriate crop section of this report.

The total research effort on Nematode Identification, Physiology, and Control at the State Stations is approximately 52.2 professional man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

Citrus and Subtropical Fruit. Additional data from long-term experiments at Tempe, Arizona, with control of the citrus nematode (*Tylenchulus semipenetrans*) by the application of 1,2-dibromo-3-chloropropane (DBCP) in irrigation water indicate that improvement in tree growth, yield and fruit size lasts for 2 years after the application of 2 gallons of DBCP per acre, or 4 years after the application of either 4 or 6 gallons per acre. If the treatment is not repeated at the end of that time, fruit size and yield again decreased. In one experiment grapefruit size dropped from 40 to 64 (needed to fill a standard field box) in one year. In another part of the same grove which had never been treated with DBCP, fruit size averaged 80 but increased to 48 the first season after treatment and to 40 in the second season. Similar results have been obtained in other experiments.

In field experiments at Orlando, Florida, growth of young orange trees infected by burrowing nematodes (Radopholus similis), root lesion nematodes (Pratylenchus sp.), and fungi was increased over a 4-year period by application to the soil of the fungicides folpet or captan, neither of which had any effect on the nematodes.

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INSECT CONTROL

Entomology Research Division, ARS

Problem. Many species of insects and mites attack citrus and subtropical fruit. They reduce the yield, lower the quality, spread plant diseases, contaminate the marketable product, and greatly increase the cost of production. There is an urgent need for research to secure more accurate biological and ecological information that will provide a sound basis for the development and implementation of improved insect control methods. Additional research is needed on biological control agents, including parasites, predators, and diseases; on the integration of biological and chemical control measures to provide safer, more effective, and more economical tools to control insects which will minimize or avoid insecticide residues and hazards to fish and wildlife. Attractants, chemosterilants and other growth-affecting materials and the sterile-male technique are among new approaches to control that need expanded investigations. Protection against introduction into the United States of tropical fruit flies or other foreign injurious insect species requires research on effective, low-cost detection methods, insect control treatments that can be used to permit movement of commodities under plant quarantine regulations, and eradication procedures for use in emergency situations to eliminate incipient insect infestations.

USDA AND COOPERATIVE PROGRAMS

The Department has a continuing program involving both basic and applied research on insects and mites infesting citrus and subtropical fruits and on treatments for control of insects and related pests in commodities regulated by plant quarantines. The program is carried on at Beltsville, Md., Honolulu and Hilo, Hawaii, Riverside, Calif., Orlando and Lake Alfred, Fla., and Brownsville and Weslaco, Tex., in cooperation with entomologists, chemists, and agronomists of the respective State Experiment Stations; also at Orlando, Fla., in cooperation with the Crops Research Division; at Hoboken, N. J., in cooperation with the Plant Quarantine Division; at Mexico City, Mexico, in cooperation with the Plant Pest Control Division and with the Defensa Agrícola of the Mexican Secretaria de Agricultura Ganaderia and on the islands of Guam and Rota in cooperation with the Department of Agriculture, Territory of Guam, and with the U. S. Navy and Trust Territory of the Pacific Islands. A satellite laboratory of Honolulu located at Kahului was closed October 31, 1963.

The Federal scientific effort devoted to research in this area totals 31.5 professional man-years. Of this number, 5.8 is devoted to basic biology, physiology and nutrition; 3.6 to insecticidal control; 1.0 to insecticide residue determinations; 3.4 to biological control; 9.7 to insect sterility, attractants and other new approaches to control; 1.0 to evaluation of equipment for insect detection and control; 4.0 to insect control treatments for commodities regulated by plant quarantines; 0.6 to varietal evaluation of insect resistance; 1.1 to insect vectors of diseases; and 1.3 to program leadership.

PL 480 research grants devoted to this area include: India: (A7-ENT-26), Biology of gall midges affecting mangoes with special reference to extent of damage; Pakistan (A17-ENT-5), Studies on scale insects, fruit flies, and mites and their natural enemies in West Pakistan; Greece (E11-ENT-1), Control of the olive fly with radiation or chemical sterilization procedures; Egypt (F4-ENT-3), Induced sterility in males of Mediterranean fruit fly as a means of controlling and eradicating that pest.

PROGRAM OF STATE EXPERIMENT STATIONS

The States are engaged in both basic and applied research on citrus and other subtropical fruit insects. Attempts to establish more effective complexes of biological control agents have led to the importation of new natural enemies from other areas of the world, the most promising of which are being reared in quantity and colonized in the field. The influence of adverse factors on native and imported biological control agents is being determined by correlation of field population counts with weather cycles and treatments and by laboratory studies of temperature, humidity and other factors.

Injurious species are being studied to ascertain the type and extent of damage produced by each, methods of predicting outbreaks, mass rearing methods, seasonal population fluctuations and other biological information upon which integrated control measures may be based.

New insecticides are being evaluated to determine the most effective methods of application, dosages, compatibility with other materials, phytotoxicity, effect on beneficial insects, safety of application and residue levels on and in fruit. Particular attention is being devoted to spray oils because of the safety of their use and the fact that no evidence of resistance has appeared in any of the insect pests for which they are being used.

New techniques for sterilization of citrus and avocado fruits against fruit flies are being evaluated, so that the produce may be moved from quarantine areas into uninfested areas without containing harmful residues.

The total State scientific effort concerned with citrus and subtropical fruit insects is 18.9 man years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Citrus Insects and Mites. At Orlando, Fla., citrus bud mites were collected for the first time. Mites were found on Valencia orange trees in three groves. Techniques are being developed for mass rearing the citrus bud mites on citrus seedlings in greenhouses.

Differences in susceptibility of 14 types of citrus seedlings to feeding by rust mites was demonstrated in the laboratory. Populations of citrus rust mites increased most rapidly on Duncan, Sour, Columbia or Navel seedlings, while pink citrus rust mites (Aculus pelekassi) increased fastest on Troyer and Columbia. The latter species defoliated Temple seedlings and caused witches-broom growth of Key lime and Sour seedlings.

Studies in the laboratory showed that the females of A. pelekassi generally outnumbered the males 3:1, and males preferred the lower side of leaves. No consistent differences in behavior of Phyllocoptruta oleivora were observed. A few females of both species were observed in which an egg had ruptured and a first instar mite could be seen within the adult.

At Riverside, Calif., migration of the citrus red mite during warm sunny days in May was studied by releasing several thousand albino mites of all stages in a mature navel orange tree and examining leaf samples at frequent intervals. Adult females dispersed more rapidly upward than in any other direction. Females were recovered 2 feet from the point of release in 6 hours, 3 feet in 2 days, 5 feet in 7 days, and 6 feet in 15 days.

California red scale fertilization studies made by isolating lemons with different ratios of males to females indicated that up to 12 females were fertilized by a single male. By placing lemons infested with female scales at varying distances in the greenhouse from a source of males, it was determined that males migrated at least 40 feet for successful matings.

In the lower Rio Grande Valley, an abrupt upsurge in brown soft scale populations occurred in late June, 3 to 4 weeks later than the similar increase in 1963. This sudden increase coincided as in the past with accelerated cotton spraying. Coincidentally, a cool, late spring delayed cotton development. The upsurge in scale was accompanied by an abrupt decrease in parasite and predator populations in groves.

2. Subtropical Fruit Flies. In tests at Mexico City substitution of torula yeast in the larval rearing medium for the Mexican fruit fly resulted in recoveries and larval weights comparable to those with brewers' yeast and at 1/3 the cost. Substitution of wheat bran and wheat middlings for part of the dehydrated carrot in the rearing formula gave promising results and induced slightly earlier pupation.

The intestinal microflora of laboratory-reared adults of the Mexican fruit fly consisted of 21 different bacteria. The bacterium occurring with the greatest frequency has been determined as belonging to the genus Staphylococcus. Study of cultures indicated that symbionts are not transmitted through the egg.

Effect of intensity of light on the Mexican fruit fly was investigated with flies which emerged and were held in darkness for 2 days, then sexed and exposed for 6 weeks to continuous darkness or continuous light at 0.2, 4.0

and 13.9 foot candles from white frosted incandescent lamps. Few eggs were laid in the absence of light and at 0.2 foot candles. Oviposition was approximately equal at 0.4 and 13.9 foot candle exposures. When flies were subjected alternately for 12 hours to complete absence of light and to red, green, yellow, blue or white light, mating began 2 hours earlier under red light than with the other colors.

Activity of Mexican fruit flies sterilized with 5% tepa and 5000 r of gamma radiation was compared with that of untreated flies by timing their movement through a series of connected compartments with 1" entrances and exits. Under uniform conditions 2.3% of the irradiated flies, 4.8% of tepa sterilized flies and 10.4% of the untreated flies reached the last compartment within the same period of time.

Adult Mexican fruit flies emerged from pupae that had been exposed to 3000 r of gamma radiation at 12 days of age. These flies laid eggs, which hatched and produced larvae but failed to develop beyond the pupa stage. Application of gamma radiation by fractionated dosages produced hatch similar to a single application.

Sterile Mexican fruit fly females attempted oviposition by insertion of ovipositors into caged grapefruit. One attempt by gamma-sterilized females compared to 20 attempts by untreated females and one by tepa-sterilized females compared to 50 by untreated females were noted.

Exposure of Mexican fruit fly eggs to gamma radiation from 10 to 1000 r has not resulted in visible mutations. Selection to eliminate the light-colored median stripe on the dorsum of the fly shows a considerable reduction in the size of the marking in the F_2 generation. A genetic marker obtained from larvae and pupae subjected to low temperatures consisted of black lines on the dorsum of the abdomen and a bar on the dorsum of the thorax.

Fluorescent dye powder impregnated on 3/16-inch squares of foam rubber in a 3" layer above pupae proved effective for marking Mexican fruit flies. As the emerging adults work through the layer of rubber to the surface, dye particles adhere to the ptilinum and remain attached when it recedes. The dye can be detected in the head under ultraviolet light or the ptilinum may be forcibly extruded. Eight colors or shades of the dye fluoresce with equal brilliance. The dyes are not toxic. Dyes can be detected in flies held in lure solution for 2 weeks and then in 70% alcohol for 2 months. No decrease in fluorescence was noted in caged flies held for over 2 months.

Liberation of only males of the Mexican fruit fly is desirable in certain sterile release studies. Laborious methods must be used at present to separate the sexes. It has been observed that males predominate early in the emergence period of any one lot of pupae. A count of flies emerging during the first day from pupae of the same age showed 1732 males and 916 females, or 65.4% males. A study for selection of a strain of early emerging males is in progress.

Longevity and dissemination of the Mexican fruit fly was studied with populations of sterile flies marked lightly with atomized colored lacquer and liberated in the State of Morelos, Mexico. Four males were captured at periods ranging from 9 months 18 days to 11 months 22 days after liberation and one male was taken 11 miles from point of release.

More than 1 million marked tepa-sterilized Mexican fruit flies were liberated at 6 locations in northeastern Mexico from Nov. 3, 1963, to Feb. 5, 1964. Two trap lines were maintained just south of the Texas border, one from Monterrey via Cerralvo to Ciudad Mier (115 miles) and the other from General Teran via China to Reynosa (107 miles). Trapping stations with 5-10 traps each were established along the lines at intervals of 10 to 20 miles. The weather with almost continuous wet northerners and temperatures in the low forties and fifties was not conducive to fly activity. Only 2 liberated flies were recovered 4-5 miles from one of the release sites 14-25 days after liberation.

Longevity and dissemination of marked ~~gamma~~ and tepa-sterilized Mexican fruit flies were studied in harvested grapefruit groves in the Mission district of Texas. A total of 9870 flies was liberated on February 6-7 and 3.3% were recovered, most of them tepa-sterilized females. Only 3 flies, all females, were captured outside the release groves, two of them at a distance of 4 miles.

In Hawaii further developments of mass rearing techniques for tropical fruit flies have reduced the cost of production from \$100 to \$94 per million. The new procedure which increases larval survival about 10% involves distributing eggs on strips of toilet tissue on top of the rearing medium instead of placing the eggs directly on the medium.

In Hawaii sterile females that emerged along with sterile males at a single release site showed only a slight response to trimedlure (a male lure) until 38 days after emergence, at which time flies had dispersed throughout the 1-square-mile trapped area and there was a sharp drop in the numbers of males responding to trimedlure. During the next 2 weeks catches of sterile females outnumbered sterile males more than 2-1 and exceeded the number caught during the first 2 weeks. Previous experience with wild flies has shown that non-mated females will respond to trimedlure when the male population is extremely low. Practically all of the sterile females captured during these studies had mated. This is further evidence of the sexual aggressiveness of sterile mated females in search of a male for additional mating.

In Hawaii a strain of melon fly with a genetic marker is being segregated by progressive selection. Results of screening about 39,000 F₇ and F₈ generation flies indicate that a pure strain with an easily recognized band across the anterior surface of the abdomen may be attainable.

In Hawaii the longevity of oriental fruit flies allowed to emerge and feed for up to 2 days in boxes used for aerial drops was reduced about 50% below that of flies emerging in cages. When water alone was supplied continuously to the boxed flies for 2 days and flies then removed to cages 47% survived 3 weeks. Only one third of the flies survived after 3 weeks when they were fed sugar, honey, and water the first 2 days. Nearly 70% of the flies that emerged directly into cages stocked with adequate water as well as sugar and honey were alive after 3 weeks.

The Medfly has been reared previously in small one ft³ cages containing 1000 flies and plastic lemons used for eggging. It converted readily to the mass production methods used for the melon and oriental fruit flies where 25,000 or more flies in 8 ft³ cages were egged with large plastic oviposition containers.

3. Southern Green Stink Bug. In order to provide stock for development of a laboratory rearing method, 10,000 bugs of all stages were collected from the field. The stock has been maintained at approximately 10,000 adults and 20,000 nymphs, and daily production of egg masses has been increased to about 135. A total of 11,589 egg masses has been obtained to date with an average of about 70 eggs per mass. Although the southern green stink bug survives on a broad range of dietary materials, including fruit fly pupae, a combination of sweet corn, broccoli sprouts, and peanuts has been used as the principal diet for production purposes.

B. Insecticidal Control

1. Citrus Insects and Mites. At Orlando, Fla., five standard acaricides applied as dips failed to prevent hatch of citrus rust mite eggs, but three materials, dioxathion, Kelthane, and carbophenothion at 20 ppm gave complete kill of nymphs hatching from the eggs. Chlorobenzilate and ethion were only partially effective as residual treatments against immature stages. Carbophenothion was not effective as a contact miticide.

In field tests using single-tree plots, ethion, ethion plus oil, and Imidan gave equal control of Texas citrus mites (Eutetranychus banksi) while zineb, NIA-9102, and Pentac permitted populations to increase and Morestan and chlorobenzilate did not affect these mites as compared with untreated plots. These chemicals gave only 3 to 6 weeks control of citrus rust mites, with ethion plus oil, Imidan, and zineb slightly more effective than the other materials. Ethion plus oil and Imidan also reduced populations of scale insects. In another test, Bidrin, Shell 7438, NIA-9203, and Dithane M-45 reduced populations of Texas citrus mites while Nabac, DuPont 328 and zineb permitted population increases 3 to 6 weeks after treatment. In this experiment zineb and Dithane M-45 were equally effective in control of citrus rust mites. NIA-9203 and Bidrin reduced populations of scale insects.

At Riverside, Calif. strains of citrus red mites resistant to demeton and ovex have been reared in the laboratory without further exposure to chemicals since 1957 and 1958, respectively. Resistance to ovex is considerably more stable than to demeton. In comparison to a susceptible strain, resistance to demeton declined from 163-fold to 10-fold in 131 generations. Ovex resistance declined from 131-fold to 78-fold in 103 generations.

C. Insecticide Residue Determinations

1. Citrus and Subtropical Fruit Insects. In the lower Rio Grande Valley, studies were conducted to determine amount and extent of insecticide drift into citrus groves downwind from cotton sprayed by airplane. Sheets of mylar plastic, 1 foot square, placed in a horizontal position showed mean deposits of methyl parathion, endrin and DDT of 192 ug at a distance of 88' downwind from the nearest row of cotton, 130 ug at 288' downwind, and 9.52 ug at 788' downwind. Amounts in ppm recovered from citrus leaves were 3.53 at 88', 2.63 at 288', and 0.91 at 788'. Rate of application per acre was 1.25 lb DDT, 0.8 lb methyl parathion, and 0.3 lb endrin. Wind speeds averaged 7.5 miles per hour. Analyses were by gas chromatograph with electron capture detector.

2. Analytical Equipment. At Hoboken, N. J., the Kitagawa gas detector tubes continued to show great promise as simple safety tools for tarpaulin fumigations to determine whether hazardous gas concentrations are present in the working areas. The methyl bromide tube was sensitive to near 1 ppm (about 1/20 the present human safety limit). The ethylene oxide tube was sensitive to near 10 ppm (1/5 the present human safety limit of 50 ppm). Its high range of 35,000 ppm has also made possible the field testing of high concentrations in the fumigation. Preliminary results with HCN and carbon dioxide tubes were promising. A new thermal conductivity unit from England showed good sensitivity for methyl bromide analysis (minimum near 1/2 oz/1000 ft³) and corroborated previous figures using other T/C sets.

D. Biological Control

1. Citrus Insects and Mites. In Florida zineb again reduced the effectiveness of natural control of Texas citrus mites in 3 orange groves. Populations of these mites on treated trees were three times those on untreated trees. Similar results were obtained with Pentac, NIA-9102, DuPont 328, and Dithane M-45.

At Riverside, Calif., the citrus red mite virus continues to show promise as a biological control agent in field tests. Spray application of virus suspensions and introduction of 5,000 laboratory-inoculated mites per tree at 6-week intervals apparently prevented mite build-up for more than a year. Infestations increased to economic levels within a few months after treatments were suspended. In another grove treatment of heavily infested plots with 10,000 inoculated mites per tree produced an epizootic which reduced the infestation below an economic level within a month.

Basic laboratory studies of disease behavior have revealed that the disease is most active in high-density populations but is not density dependent. This finding has been supported by subsequent field observations. At least a 3-fold increase in virulence of virus suspensions was obtained by delaying the processing of the dried inoculum until it was actually sprayed in the field. Infected mites are able to transmit infection within 48 to 72 hours after having been inoculated. In studies to determine mode of transmission, mites fed through plastic membranes on virus-sucrose solutions became diseased. Transmission appeared to occur when healthy mites were fed on sucrose solutions previously fed on by infected mites. Basic studies by the Insect Pathology Pioneering Research Laboratory revealed that the virus yield in diseased mites is approximately 5% by weight.

At Lake Alfred, Fla., the introduction of the predatory mite Amblydromella rickeri continued over the past year. No evidence of an overwintering establishment of this predator was obtained. Laboratory studies with Phytoseiulus persimilis on citrus mites were not favorable enough to attempt field colonization of this mite. Studies of mite populations in sprayed and unsprayed groves during the past season failed to reveal a predator or disease that could be depended upon to give consistent control of mite populations.

Armored scale populations indicated a change in the dominant species present in Florida citrus. Since Lepidosaphes beckii and Chrysomphalus aonidum, formerly number 1 and number 2 ranking scale problems in the State yielded to biological control, the dominant species are now Lepidosaphes gloverii and Parlatoria pergandii with a recent increase in Aonidiella citrina.

Studies of the biology of Micromus posticus and M. subanticus, two aphid predators, revealed a tremendous biotic potential for the two species, but these predators were not the most common species of aphid predators observed. A parasite, Anacharis sp., attacked larvae of M. subanticus but not larvae of M. posticus.

In the lower Rio Grande Valley, seven species of parasites, 5 from Israel and 2 of the most effective California species, apparently failed to become established after valley-wide releases of large numbers.

Two species of Coccinellidae, Thalassa montezumae and Chilocorus cacti proved much more effective in controlling brown soft scale on caged citrus than the dominant native parasite Coccophagus lycimnia. Five adult coccinellids per cage reduced scale populations 58 to 65%. Ten to 40 adults of C. lycimnia reduced scale populations 0 to 30%.

In a backyard urban area some distance from spraying activity, brown soft scale on citrus caged to protect it from natural biological control factors increased from 1400 to 5100, while on an uncaged tree the population decreased from 1900 to 180 in one month. Percentage of parasitism was 1.3%

on the caged tree and 3.9% on the uncaged tree. Factors other than parasites may have been responsible for the reduction of scales on uncaged trees.

Parasites were caged for one week on terminals of citrus at each of 3 locations which had been exposed to insecticide drift from nearby cotton that had been sprayed six times by air. Only 1% of the 600 parasites on terminals at a distance of 788' downwind survived and none at distances of 88' and 288'. There was little difference in survival on terminals on windward or leeward sides of the trees. Parasitism was more than twice as high on caged terminals on the windward side of the trees than on the leeward side, which was unexpected. However, the number of scale on windward terminals was about 1.6 times as heavy as on leeward terminals, which may account for the difference in parasitism.

2. Subtropical Fruit Flies. In Hawaii parasitism was high in oriental and Mediterranean fruit fly hosts and ranged from 0 to 95%. Parasite activity was exceedingly heavy in many of the preferred hosts with Opius oophilus continuing to be the dominant and most effective parasite among the many species that have been released to combat fruit fly pests. The hosts yielding average parasitism greater than 50% were banana (95%), surinam cherry (93%), strawberry guava (72%), mountain apple (64%), coffee (62%), Euphoria didyma (61%), methyley plum (60%), and guava (55%). Opius vandenboschi, O. longicaudatus, and O. fletcheri continued to be recovered in small numbers in a few of the fruit collections. Two polyembryonic parasites, Tetrastichus giffardianus and Syntomosphyrum indicum, were recovered from wild momordica and banana, respectively.

F. Insect Sterility, Attractants and Other New Approaches to Control

1. Citrus Insects and Mites. At Orlando, Fla., dipping citrus rust mite infested plants in chemosterilants at concentrations of 1000 to 4000 ppm showed that apholate was partially effective in reducing hatch of the mite eggs. Tepa and metepa were toxic to mites at the higher concentrations. Hempa and farnesyl methyl ether had no effect on populations of these mites.

At Riverside, Calif., tepa, apholate, and hempa were applied to larval males and pre-second molt females of California red scale on lemons. All 3 sterilants were more toxic to males than to females. The LC₅₀ for tepa was 0.5% for males and 2.3% for females, and for hempa 0.2% for males and 3.3% for females. Apholate was practically non-toxic. No evidence of male sterilization was detected.

2. Subtropical Fruit Flies. Studies in Florida showed that $\frac{3}{4}$ " x 2" wicks in plastic Mediterranean fruit fly traps held 3.5 times as much and dispensed 70% more trimedlure as did $\frac{3}{8}$ " x 2" wicks. The larger wicks need retreatment on a 6 to 8 week schedule compared to 3 to 4 weeks for the smaller wicks. Loss of oil of angelica during periods of cold weather amounted to 74% of the loss during warm weather compared to 36% for

trimedlure and only 3% for medlure. Wicks (3/8" x 2") should be retreated at intervals of 1 week with oil of angelica, 4-6 weeks with trimedlure or 8-10 weeks with medlure during winter months in Florida. These data indicate that medlure may not be a satisfactory lure for Medflies in Florida during periods of low temperatures.

Results of tests conducted in Hawaii with various dyes to mark fruit flies indicated that Eosin Y, Brilliant Yellow, and Calco Blue (oil soluble) dyes mixed with pupae at 4g/ liter or covered by fine vermiculite dyed with 10 g/ liter gave equally good results. Emergence and longevity were unaffected. The two new colors retract into the head of the flies with the ptilinum upon emergence and can be detected by crushing the head with a small amount of acetone. The Calco Blue has effectively marked melon flies released on Rota for as long as they lived--up to 4 months after the last release.

In Hawaii methods of dispersing lure-toxicant combinations for the male annihilation method of eradication have been improved. The standard cane-fiber wafers saturated with trimedlure, cue-lure, or methyl eugenol, each in combination with 3% naled, continue to kill flies attracted to them on the ground for several weeks or months. Other materials tested including large flakes of vermiculite, corncob grits, and pressed wood pellets, were less effective than the cane-fiber wafers. Cue-lure applied to foliage lasted much longer than other lures. Its effectiveness was doubled by inclusion of monoglycerides of lard and substitution of Imidan (3%) for naled. Generally baits applied to the foliage lost their effectiveness more rapidly than baits in cane-fiber wafers.

The oriental fruit fly has apparently been eradicated from the 210 square mile island of Guam by sterile fly releases at an overall cost of less than 4¢ per acre. During September 1963 low populations of the oriental fruit fly were found only in steep narrow gulches of northern Guam that were protected from typhoon winds. Typhoon Karen and Olive, which occurred in December 1962 and May 1963, respectively, destroyed most of the tree fruit host plants of this fly. A release of 1.2 million sterile oriental fruit flies at 5 points across the north end of the island close to the mouth of the valleys was made for the purpose of studying fly movement, longevity, and the effectiveness of the sterile laboratory white-marked strain. Flies from these releases spread downwind as much as 12 miles in the same pattern as had been noted for the wild flies captured in the few weeks before the release. Most of the marked oriental fruit flies disappeared within a month, and at the end of that period no wild flies were coming to the traps. Two wild flies were captured in the middle of the island fifteen miles from the release sites and additional weekly releases were made across the north end and near the areas where the two wild flies were captured. No more wild oriental fruit flies were caught on the island from November until late March, when two additional flies were taken near the extreme south end of the island. Infested imported mangoes were the suspected source of these flies and a quarantine was established to prevent importation of oriental fruit fly host fruit. No additional wild flies were found in 118 traps operated on the island for more than 100 days.

In Hawaii complete sterilization of both sexes of the oriental fruit fly, melon fly, and the Mediterranean fruit fly was obtained by dipping pupae in a 5% solution of tepa. Higher concentrations of apholate, tretamine, and metepa were generally required for the sterilization of the Mediterranean fruit fly.

A 24-hour exposure of male Medflies to a chemosterilant coating on the underside of a masonite disk two feet in diameter, with a protected wick treated with trimedlure placed in the center as an attractant, resulted in either complete elimination or marked reduction in hatch of eggs from females with which these flies were mated.

Since 1954 the Plant Pest Control Division, in cooperation with the California Department of Agriculture and the Defensa Agricola of the Mexican Secretaria de Agricultura y Ganaderia, has conducted a program of spraying in local areas along the Mexico-California border where Mexican fruit flies have been periodically detected and presumed to have been brought into Northwestern Mexico in infested fruit from the interior of Mexico. This repeated spraying of urban properties has become annoying to the residents and opposition has been encountered. Beginning in April 1964 the Entomology Research Division cooperated in a program to determine if suppression of these introductions by periodically releasing large numbers of sterile male Mexican fruit flies could be substituted for the spray program. The flies were reared, chemically sterilized, and marked at the Mexico City laboratory and flown to northwest Mexico for the weekly releases ranging from 45,000 to approximately 200,000 flies.

F. Evaluation of Equipment for Insect Detection and Control

1. Subtropical Fruit Flies. A 12,700 ft³ fumigation chamber with a concrete and steel floor and return ducts to the floor for recirculation was tested at Tuxpan, Veracruz. Gas distribution was based on ethylene dibromide recovered at four widely separated points in the room during fumigation of oranges in sisal mesh bags. A 40% load was treated with 9 oz/1000 ft³ and a 55% load with 11 oz. Samples of the fumigant were taken simultaneously at the beginning of the treatment period, after 30 minutes and after 2 hours. There was little difference in the amounts of EDB recovered at four sampling points in the 55% load and no difference in the 40% load.

In Hawaii trimedlure-baited traps in non-host plants caught less than half as many Mediterranean fruit flies per trap as those in host plants in three experiments involving 0.5 million sterile flies. Traps in fruiting and non-fruiting hosts caught equal numbers. Most of the flies in the three traps nearest to the release site were caught within 24 hours after emergence. Some appeared 800 feet away within 24 hours. At 2400 feet elevation the peak catches occurred between 11 and 14 days after emergence.

G. Insect Control Treatments for Commodities Regulated by Plant Quarantine

1. Subtropical Fruit Flies. Larvae of the Mexican fruit fly in fruit fumigated with ethylene dibromide die slowly. The delayed mortality caused no problem until larvae still capable of movement were found in oranges which had been fumigated at Tuxpan, Veracruz, using the authorized schedule. Fruit had been loaded on ships immediately after treatment and stored at 42°F during the 2 to 3 day voyage to Florida Gulf Coast ports. At Mexico City studies were conducted to determine the longevity of Mexican fruit fly larvae in grapefruit fumigated at 65-70°F with 24 oz of EDB and stored at temperatures ranging from 78 to 42°F. Live larvae were found at temperatures and storage periods as follows: 78°--87 hr; 70°--69 hr; 63°--161 hr; 50°--262 hr; and at 42°--120 hr. Larvae pupated after storage for 10 hr at 70°, 50 hr at 50°, and at 48 hr at 42°. The only adults which emerged were at the 48 hr storage at 42°.

Midseason oranges were fumigated with 24 oz EDB at 68°F with a 50% load and waxed after fumigation. EDB residues determined as inorganic bromide in ppm ranged from 55.4 at 12 hr to 4.2 at 20 days. Valencia oranges were fumigated with 24 oz EDB under the same conditions as the midseason oranges and half were waxed after fumigation. Residues as inorganic bromide in ppm ranged from 44.6 at 1 day in waxed fruit and 36.2 in unwaxed, to 12.4 at 15 days in waxed and 0.4 in unwaxed. At 21 days, 2.2 ppm remained in waxed fruit.

Tolerance tests with midseason oranges from Veracruz showed that fruit from that region treated with a 24 oz EDB dosage are highly susceptible to injury; over 80% were blemished or rotted. Tolerance tests with nearly a ton of naval oranges, early oranges and tangerines from the Montemorelos region showed no injury from a 24 oz dosage of EDB and rot was no greater than in the controls.

A dose of 25 kr of gamma radiation was sufficient to prevent emergence of flies from sweet peppers, eggplant, zucchini squash, or avocados containing eggs and larvae of melon, oriental, and Mediterranean fruit flies. No pupae were obtained from tomatoes irradiated at the same dose. Load densities in these treatments were approximately 12-22 lb/ft³. Tomatoes of variety N-5 tolerated treatments at doses up to 50 kr and cold storage at 55°F for 5 days. Zucchini squash were slightly softer after treatments up to 50 kr and cold storage at 55°F for 6 days. Black Beauty eggplant became moldy and decayed after treatment at 100 kr and storage at room temperatures (79-88°F). The internal or external characteristics of the eggplants were normal at doses up to 50 kr. The fruits were much firmer at 200 kr than at 50 kr. The calyces were browned at all doses.

2. Miscellaneous Crops. At Hoboken, N. J., honeydew melons from Chile tolerated methyl bromide fumigation of 4 lb for 2 hr at 40-49°F or 3 lb for 2 hr at 50-59°, with a small margin of safety. Bromide residues (determined by Dow Chemical Company) were less than 5 ppm--well within the present 20 ppm

tolerance. Even though the residues were low, it was shown that sufficient methyl bromide penetrates the skin and pulp of the melon to give good fumigation efficiency.

Cooperative tests with the Plant Quarantine Division and the Forest Service indicated four species of dry conifer seeds would tolerate standard methyl bromide atmospheric or vacuum fumigation schedules with 1 or 24 hr aeration, but high moisture seed (10 or 15%) appeared injured when aerated for only one hour after fumigation. Vacuum fumigation may also have injured some seed with excessive moisture (15%).

Carboxide (ethylene oxide 10%-carbon dioxide 90% mixture) was very effective in small-scale fumigations against a bagworm, Brachycyttarus subteralbatus, intercepted in California on military cargo returned from Vietnam. A schedule of 15 lb for 24 hr was suggested for emergency, provisional use. Information developed on Carboxide fumigation over the past few years also made it possible to suggest its use for a quarantinable cabbageworm infesting military household effects.

H. Insect Vectors of Diseases

At Orlando, Fla., studies on aphid transmission of tristeza virus have shown no increase of tristeza virus due to alternate host plants of aphids, pre-treatment starvation of aphids, acquisition or transmission feeding time, maturity of aphids, age of source of inoculum, or age of indicator plants. Aphids commonly found on citrus were also found on Spanish needles, sow thistle, black nightshade and occasionally on other weeds in citrus groves.

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CROP PEST CONTROL TECHNIQUES AND EQUIPMENT
Agricultural Engineering Research Division, ARS

Problem. Many pests attack economic crops in the United States, resulting in billions of dollars of loss to the farmer each year. Plant diseases, weeds, insects, and nematodes are examples. Every method to control or eradicate any of these pests requires some type of equipment. Effectiveness of the equipment necessary may be essential to the success of the method which is attempted or recommended.

Thus, equipment to control a wide variety of pests on a wide variety of crops is required. This requirement is partially met by the sprayers, cultivators, dusters, and soil injection equipment now available. However, mechanical cultivation does not always produce satisfactory weed control, and it is time consuming and costly. It is believed that with sprayers and dusters now used, often no more than 10 to 20 percent of the chemical goes onto the plant. Methods of applying nematocides in the soil do not always result in uniform nematode control, and untreated soil below the treated zone, in untreated pockets, and at the soil surface, provide sources for quick reinfestation.

There is need for improved methods of much greater efficiency for applying pesticides to plants and the soil. This implies a need for considerable fundamental study of small particle behavior, of radically new methods of applying chemicals, and of the movement of liquid and gaseous chemicals in the soil. The sales of present equipment are not great enough, nor are the manufacturers large enough, to permit industry to make a very great investment for research in this field.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers, physicists, and mathematicians engaged in both basic studies and the application of known principles to the solution of farmers' problems. Cooperation is with the State Agricultural Experiment Stations of the states mentioned, unless otherwise noted. At Wooster, Ohio, basic research is conducted on fundamental studies of aerosols and on various spray formation devices. Soil fumigation research also is conducted at Wooster, Ohio. Aircraft application equipment research is studied at Beltsville, Md., in cooperation with the Forest Service.

The Federal scientific effort devoted to research in this area totals 14.4 professional man-years per year. Of this number 1.7 is devoted to basic studies in aerosols and spray formations; 1.0 to soil fumigation; and 1.0 to aerial spray equipment for forest insect control.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 2.7 man-years is devoted to this work on all crops. Figures are not available for work on citrus and subtropical fruit.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Studies in Aerosols and Spray Formation

1. Mathematical and experimental studies on the basic transport, spreading, and distribution processes for fine particles suspended in turbulent gases were continued at the Pioneering Research Laboratory on Physics of Fine Particles at Wooster, Ohio. An instrumentation system is under development for measuring the distribution of fluorescent-traced particles on deposition surfaces to facilitate the study of relations between deposit distribution and the turbulence producing it. A method of spectral analysis has been developed which appears to be applicable to the measurement of surface deposit, but which needs further study. The use of a tape recorder has made experimental procedure immeasurably easier than if one attempted to process the "live" signal directly. Additional work is being carried forward in the areas of heat and moisture diffusion in fine-particle starch doughs, and in electrical diffusion of clay suspensions.

B. Soil Fumigation

1. Field treatments were made in cooperation with the Ohio Station in order to study and develop methods and equipment for applying chemicals to soil for the control of crop pests. A number of volatile materials are now available in pressurized cylinders or bottles similar to the containers used for oxygen, nitrogen and other compressed gases. By using an appropriate regulator, these materials are easily applied by the field cultivator equipment with injector blades. Applications of this type made for control of Verticillium in vegetable plantings gave substantial increases in yield, but the materials do not give the desired control of this disease. Measurements made of cherry trees planted in soil treated with several different nematocides in 1957 and 1960 show increased twig growth and greater spread of branches than in untreated plantings.

Applications of herbicides by a rotary tiller type of applicator, operated with forward travel per blade cut ranging from 1.5 to 4.7 in., show best result with the short cut. The short cut is believed to give a better resultant mixing of non-volatile chemicals with the soil.

Latex asphalt and wax emulsions were applied to soil as surface mulches. This had previously been found to increase plant growth including weeds. Several formulations including different herbicides were applied. Generally these formulations appeared to produce some seedling injury and reduction in stand in vegetables on which they were used.

C. Aerial Spray Equipment for Forest Insect Control

1. Since a helicopter was not readily available at Beltsville, some spray studies were made in cooperation with the Forest Service, using a PA18A fixed wing airplane at 45 to 50 m.p.h. to simulate helicopter application. The degree of spray atomization is an important factor affecting the distribution and effectiveness of aerial sprays. There is considerable information on the atomization produced by various nozzles on fixed wing aircraft but for helicopters such information is very limited. Two flat spray pattern nozzles, T8004 and T8006 (Spraying Systems Co.) with flow rates of 0.4 and 0.6 g.p.m. were used with the orifice directed forward and down about 40 degrees to the thrust line of the plane. The atomization was 176 microns mmd from the former and 179 from the latter--no significant difference. About this same atomization (180 microns mmd) was produced by a hollow-cone nozzle, D4-25, with an output of 0.29 g.p.m. The orifice was also directed forward and down 40 degrees. Thus, for this atomization of 176 to 180 microns, the flat spray nozzles would be preferable to the hollow cone nozzles because a smaller number of them would be required to provide a given output.

On the studies with heavy aircraft a series of flights were made with a TBM airplane at 200-ft. altitude to study spray distribution from this height as compared to that from lower heights (100 to 150 ft.). Flow rate of the plane was 107 g.p.m. for an application of 1 g.p.a. over a 300-ft. swath at 170 m.p.h. Based on a total of 20 flights, 10 at each height, there was no difference between the two heights at the 0.25 g.p.a. deposit level. At deposit levels of 0.1 and 0.2 g.p.a. swath width was slightly greater at the 200-ft. height but the reverse was true at deposit levels greater than 0.25 g.p.a. These tests showed that the present recommendations of a 300-ft. swath for a TBM will result in a deposit of not less than about 0.15 g.p.a. over this width. Considering overlap of adjacent swaths, deposit should be adequate for control of most forest defoliators. The average spray recovery was 73 percent.

A pilot test of an aerial application of B. thuringiensis, a biotic insecticide, was carried out for control of the gypsy moth in New York State. A Piper PA18A was used to apply 2 gal. per acre using a 75-ft. swath width. A one percent concentration of a water soluble fluorescent tracer, Laucophor C 6202 (Sandoz Chemical Works) was added to the spray mix. Samples of the spray were collected on white Kromekote cards placed in the plots. After spraying, the cards were irradiated with ultraviolet light. The tracer was found to be a very good indicator of spray deposit. The application reduced gypsy moth populations but did not effect acceptable control. No further large scale field applications of this material will be made until additional laboratory work is done to improve its toxicity.

The development of methods for measurement of spray deposit by use of fluorescent tracers has been continued. Attempts are being made to quantitatively assess spray deposits on paper cards. Position and intensity of ultraviolet excitation source has been studied and an enclosure constructed in which sprayed card samples can be assessed. Calibration work

is in progress. The measurement of water sprays either by fluorescent tracer or estimation from dyed card standards is an important problem to be investigated during the coming year.

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CROP HARVESTING AND HANDLING OPERATIONS AND EQUIPMENT Agricultural Engineering Research Division, ARS

Problem. This area is concerned with the development of equipment and methods for efficiently harvesting and farm handling crops, with emphasis on the preservation of inherent qualities during these processes. The cost of harvesting and farm handling of most crops is the major expense of production, often amounting to over half of the total returns to the producer from the sale of the product. In addition, supply and adequacy of manpower for these operations are becoming progressively less satisfactory.

While research on harvesting equipment and methods has led to much improvement in the reduction of production costs of such crops as grains and forage, much additional work needs to be undertaken, both basic and developmental, in order that all crops may be mechanically handled. Harvesting equipment research for fruits, only recently initiated, has already resulted in sizeable cost reductions, but the potential savings for these crops and vegetables are enormous. Tobacco requiring over 400 man-hours per acre currently, also has long needed mechanization.

The problems associated with harvesting and handling are interrelated with crop growing, processing, and storage thus necessitating close cooperation with engineers in other research areas and with scientists in other disciplines.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of crop harvesting and handling. Citrus fruit harvesting research is being conducted at Lake Alfred, Florida; Davis and Riverside, California; in cooperation with the respective State Experiment Stations. The Federal engineering effort devoted to research in this area totals 29.0 professional man-years, of which 4.0 is on citrus.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 44.2 professional man-years is devoted to the broad area: figures not available for work on citrus.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

Citrus Harvesting Equipment

Harvesting citrus. Over fifty million dollars is paid to workers who hand pick the citrus crop. The rapidly decreasing availability of suitable labor for picking citrus has created a serious need for improved methods and equipment for harvesting this crop.

In Florida tree plots were leased for a 5-year period for fruit harvesting studies in the Lake Wales area where damage from the December 1962 freeze was not extensive. Tree shaking trials were conducted on Pineapple oranges and Marsh grapefruit to determine the effect of time of harvest on fruit removal throughout the season; effect of shaking stroke and frequency on fruit removal; effect of fruit hanger length on removal; and effectiveness of a chemical loosener on fruit removal by shaking. A commercial tree shaker, mechanized catching frame and handling system were studied. Variables measured for comparative purposes and future design criteria were: shaking amplitude and frequency, percent solids and acids in the fruit, and bonding force of fruit to stem. Fruit removal ranged from 77 to 91 percent in Pineapple oranges and from 89 to 95 percent in Marsh grapefruit. Oscillating Air Blast trials were made with the air machines previously developed by the Citrus Experiment Station and prototype oscillating air machine loaned by Food Machinery Corporation. Comparative studies were made of different air oscillating mechanisms to determine the most efficient shaking action in terms of fruit removal. Harvest tests were made to determine the optimum air velocity and exposure time of the tree to the oscillating air. An air velocity of approximately 125 m.p.h. at a machine ground speed of one-fourth m.p.h. provided the best fruit removal but caused the most severe leaf damage. Fruit removed in this trial averaged 74 percent in Pineapple oranges and 80 percent in Marsh grapefruit. A catching frame was constructed to work with this continuous type harvest system. Rotating Auger Spindles previously tried by a cooperating agricultural engineer, Florida Citrus Commission, were remounted and briefly tested. Considerable work was done to design and mold new auger configurations from room temperature curing plastics because of poor service life of the previous hand made neoprene augers. Several commercial picking aids for positioning the fruit picker in the tree were observed but none were developed to the point where they could be evaluated by project personnel. Field handling of pallet boxes was observed and a time study made on a "Lightning Loader" boom lift mounted on a "goat" truck. The loader boom, employing a grapple-type lift raised the wooden pallet boxes by the top onto the "goat" bed. This is a versatile system with a minimum of equipment. Work on all of the above harvesting methods will continue in order to determine their effects on tree growth, fruit yields, and need for changes in cultural practices.

In California, the characteristics of electrical conductance, back scatter of nuclear emission, surface temperature and light reflectance was measured for fruits and other parts of the tree to determine their effectiveness as differentiating features. The studies indicate that there is not sufficient difference in temperature and electrical conductance between fruit and leaves, etc. to be used in selection. The preliminary investigations of back scatter and light reflectance appear worthy of further investigation. Depending on the direction of pull the form of separation were noted to be: (1) Perpendicular to the stem axis, without the button; (2) colinear with the stem axis, a variation of above the button and below the button with some plugging; (3) twisted about an axis perpendicular to the stem axis, without the button; and (4) twisted about the stem axis, above the button.

Forces that resulted in removal for these different tests were measured. Tests were performed to determine the extent of damage incurred by oranges in falling through the tree from the point of attachment onto a special catching cushion at the ground. A later test was conducted on pruned and nonpruned trees. Results so far have not been conclusive.

Dates grow on palm trees which are 30 to 60 feet high and it is becoming difficult to find workers to hand-pick fruit in these tall trees. Refinements were made on the mechanical harvesting and bulk handling systems developed on this project last year. In Fiscal Year 1964 the systems were used in harvesting over four million pounds of dates. (Two years ago all dates were hand picked and handled in small containers.) Where large acreages are harvested, costs are reduced over 50 percent and labor requirements reduced to one-fifth of conventional harvesting requirements. A new system of harvest in which dates are removed on the tree without cutting the bunch from the palm was tested and shows promise. The hand-carried vibrator designed and constructed for this work removed 100 percent of the dates from a mature bunch in less than three seconds.

II. NUTRITION, CONSUMER AND INDUSTRIAL USE RESEARCH

UTILIZATION RESEARCH AND DEVELOPMENT

Processing and Products

Southern Utilization Research and Development Division, ARS

Problem. The citrus and subtropical fruit production of the Southern

Region is an expanding industry with the need for the development of better, as well as new-type consumer products, and for the improvement of present or invention of new processing procedures and machinery. These advances are required to regularly utilize the currently large production, particularly of oranges and grapefruit, and the anticipated higher production of these fruits, to the economic advantage of the growers and consumers. Basic research is needed to lay the groundwork for these advances. This research is needed, for example, on the composition and physical nature of essential oils, flavonoids, including bitter constituents, constituents responsible for oxidized off-flavors, carotenoids, and the like, which determine many of the sensory characteristics, and which affect product quality and stability. Other problems whose solutions are dependent upon the availability of more detailed compositional and physical data are: cloud stability, gelation, discoloration, fermentation, and the like. Increased production of citrus has stimulated the development of new products but many of these are urgently in need of improvement which will depend in part upon advances in basic research. New products are needed to attract new markets and also to reduce packaging and shipping costs. Research is needed to improve frozen citrus concentrates as processing procedures change, to develop better high density concentrate products, citrus powders, chilled juice and section products, pulp-fortified products, and to develop new or improved canned products which have a natural fruit flavor. Research is especially needed on grapefruit to develop practical methods for reducing the bitterness and harshness of juice products and to increase the use of grapefruit juice base in mixed fruit juice blends, drinks, concentrates and the like. Along with progress on product development there is a serious need to improve the actual processing procedures, processing equipment, and packaging operations and materials, to obtain and maintain the most desirable fruit characteristics. As an illustration, research is needed to develop less expensive dehydration equipment and an improved process for the production of citrus powders.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving biochemists, organic chemists, food technologists, and a chemical engineer engaged in both basic and applied utilization research studies on citrus and subtropical fruits of the Southern Region to develop new or extended uses for these commodities.

Research to develop basic information on chemical composition and physical properties of citrus and subtropical fruits, and their products and by-products is conducted at the U. S. Fruit and Vegetable Products Laboratories

at Weslaco, Texas and Winter Haven, Florida. This information provides the necessary basis for efficient research in developing new and improved food products and processing technology. At the Weslaco Laboratory the program includes investigations of the biochemical mechanism of the conversion of precursors to carotenoids in grapefruit as a basis for improvement of processing characteristics of and products from colored grapefruit. The Texas Agricultural Experiment Station (substation 15, Weslaco), Citrus Rootstock Investigations Laboratory (CR, ARS, Weslaco), and the Texas College of Arts and Industries are providing grapefruit of known history and conducting, or cooperating in conducting, on-the-tree tests. Additional research on chemical composition and physical properties is carried out under contract at the University of Oklahoma Research Institute, Norman, Oklahoma, on investigations of the effect of maturity of grapefruit on total flavonoids, naringin, and poncirin; and on the chemistry and nature of naringin and naringin-derived compounds to provide a scientific basis for the control of bitterness in processed grapefruit products. At the Winter Haven Laboratory the program includes research to identify recently isolated flavones and other neutral orange peel constituents and evaluate their relation to bitterness and harshness in orange products. Investigations are also in progress on the composition of essential oils in citrus products particularly orange, to provide a basis for improvement in quality and uniformity of citrus products; on investigations of the chemical and physical nature of components of cloud of orange juice to provide better understanding and control of factors affecting stability of orange juice products; and on investigations of the identities, quantities and chemistry of components in Florida grapefruit responsible for excessive bitterness and harshness in processed products. Close consultation is maintained with the Florida Agricultural Experiment Station (Citrus Experiment Station, Lake Alfred) and the industry.

Research to develop new and improved food products is carried out at the U. S. Fruit and Vegetable Products Laboratories at Weslaco, Texas, and Winter Haven, Florida. At the Weslaco Laboratory the major applied effort is to develop products which will make greater and more efficient use of grapefruit. Emphasis at the present time is on the utilization of natural and debittered grapefruit juice and puree as bases for the development of improved fruit juice blends, drinks, and concentrates. This research is being carried out in part in cooperation with several state and private organizations. The cooperators provide fruit or raw materials, such as pulp and juice, of known history. Processing plant facilities are available from the Texsun Citrus Corporation (Weslaco) and Rio-Vac, Inc. (Harlingen). Formal agreements exist with the Texas Agricultural Experiment Station (College Station and Weslaco), with Texsun Citrus Corporation (Weslaco) and with Rio Farms, Inc. (Edcouch). Informal cooperation is maintained with Texas Citrus Mutual, Inc. (Weslaco), Texas Cannery Association (Weslaco) and such other organizations as are found necessary for the procurement and processing of fruit. At the Winter Haven Laboratory research is in progress to develop high quality, "instant" citrus powders by new and improved processing technology as described below.

In the field of new and improved processing technology, research is being carried out at the U. S. Fruit and Vegetable Products Laboratory, Winter Haven, Florida, to determine how the "foam-mat" type of air-drying can be applied for the preparation of dried citrus products of optimum flavor and stability. Foam-mat drying of orange juices, and grapefruit juices, is currently being studied. This research is conducted in cooperation with the Western Utilization Research and Development Division (ARS) and the Florida Citrus Commission under a formal memorandum of understanding. Additional research on new and improved processing technology will be carried out under contract at the Citrus Experiment Station, University of Florida, Lake Alfred, Florida, on the development of a practical and efficient pilot plant scale process for the production of enzymatically debittered grapefruit juice and products with improved flavor, product stability and storage characteristics.

The Federal in-house scientific effort at the Southern Division devoted to research in this area totals 20.9 professional man-years. Of this total 12.8 is devoted to chemical composition and physical properties, 2.8 to new and improved food products, and 5.3 to new and improved processing technology. The contract research involves an additional 1.9 man-years, 1.4 being on chemical composition and physical properties, and 0.5 being on new and improved processing technology.

PROGRAM OF STATE EXPERIMENT STATION

The States are engaged in research on the utilization of citrus and subtropical fruits in an effort to expand markets through increased use. Research on citrus begins with efforts to reduce decay during storage and transit through control of the physical, biochemical and physiological changes in citrus during handling--i.e., the effects of precooling and study of factors of temperature, humidity and air flow during cooling.

New product studies involve determination of the basic product characteristics, flavors, types and components and relate these to market demands. A thorough examination of the sources of flavor of some common foods including citrus is in progress. A phase of this program deals with the effects of oxidation and/or hydration on the flavor and aroma of the terpenes of citrus and the role structure plays in odor production. Conversion of citrus terpenes to useful chemical compounds is also under study. Another study has as its goal to extract, separate, identify and determine quantitatively each of the volatile components responsible for the natural flavors and occasional off-flavors in citrus fruits, citrus oils and processed citrus products.

The characteristics of commercial frozen Florida orange concentrate and superconcentrate are frequently determined to establish physical and chemical characteristics of the products. Base juices are prepared from citrus fruits and used to determine the effects of the fruit components on the characteristics of frozen citrus concentrate.

Firming of canned grapefruit sections with calcium salts and other materials is also under study. Characteristics of canned and concentrated juices are determined initially and after storage at elevated temperatures.

Utilization of citrus waste is receiving attention. In one study, isolated cultures from natural sources are being used to investigate production of glycerol and glycols from citrus wastes by fermentation.

The program with other subtropical crops such as guava, mango, soursap, banana, pineapple, coffee, and plantain includes production of freeze-dried products of high quality and good storage life. The economic feasibility of expanding markets for subtropical agricultural products through processing and utilization of new products is being further tested by preparation of soft drinks from tropical fruits--carbonated and noncarbonated, canned and bottled. Basic biochemical and microbiological studies of tropical foods are directed to discovery of special methods, special properties or nutritional qualities which may be used in new product development. Production of such products as banana puree, fried snack items, flakes, flours, fruit powders, flavoring extracts, candied items, canning syrups, nectars and juices is under study.

In addition, attempts to isolate the enzymes of fig latex are underway. The isolated proteolytic enzymes are characterized as to molecular weight, activity and amino acid composition.

Two stations, Hawaii and Puerto Rico have programs designed to improve the economic condition of their coffee industries. These researches embrace work on the microbiology of the coffee fermentation process, on the drying of coffee, and on the quality and acceptability of the final product.

The total research effort in citrus and subtropical fruit is about 21.6 professional man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Chemical and Physical Properties of Flavoring Constituents of Florida Citrus and Subtropical Fruit Products. In basic work on the composition of essential citrus oils, a new terpene (2,4-p-menthadiene) and two new sesquiterpenes (valencene and β -copaene) have been isolated from orange oil. β -copaene has also been isolated from grapefruit oil. The sesquiterpenes copaene, α -ylangene, β -elemene, α - and β -humulene, and delta-cadinene have been shown to be constituents of both orange and grapefruit oil. β -ylangene and valencene are two of the major sesquiterpenes in orange oil; valencene, the major sesquiterpene in orange juice; and β -caryophyllene, the major sesquiterpene in grapefruit oil. The structure of both α - and β -ylangene has been determined, the former being stereoisomeric with copaene. Valencene possesses nootkatone structure, whereas β -copaene, except for having

an exocyclic terminal double bond, is identical to α -copaene. Research progress has been aided by development of a thorough, rapid method for determination of terpenes and sesquiterpenes in citrus oils by use of the combined Time-of-Flight Mass Spectrometer and capillary gas chromatograph. As a continuation of the present project, composition studies will be pursued under a new related project. The research will include elucidation of structure of flavor-contributing compounds and particular emphasis will be placed on alcohols and compounds of low molecular weight (high volatility). (S3 2-36).

2. Investigation of Bitter Principle and Flavonoids in Citrus Products.

A thin-layer chromatographic system has been devised to permit separation and form the basis for quantitative determination of the five flavones thus far encountered in the neutral bitter fraction of orange peel juice extract. Included among these flavones are tangeretin, heptamethoxyflavone, nobiletin, sinensetin and new flavone. Preliminary work on the new unidentified flavone suggests that it is a tetramethoxyflavone, perhaps the 5,6,7,4' compounds. In some samples, there was evidence of a second unknown constituent, which has not as yet been isolated. In contrast to prevailing thought, orange peel juice produced late in the 1962-63 season appeared to have increased bitterness compared with that produced earlier; yield was also decreased. However, because of the severe freeze in December, 1962, these data may be atypical. Initial monitoring tests on orange peel juice for the 1963-64 season revealed a slightly lower taste threshold, a slightly higher benzene extract content, and an apparently greater contribution of the neutral fraction to total peel juice flavor than those observed for corresponding periods of the preceding season. If these trends are maintained throughout the season, the information will be of practical importance in commercial extraction operations. Research will be continued under a new project to identify recently isolated flavones and other neutral orange peel constituents and to evaluate their relation to bitterness and harshness in orange products. (S3 2-37).

The University of Oklahoma Research Institute is conducting contract research to investigate the changes that occur as grapefruit matures. Efforts are continuing to develop a quantitative analytical procedure for the determination of flavanones, including bitter constituents, in grapefruit juice and products. The procedure under investigation involves quantitatively isolating the flavanones, separating the individual flavanones (naringin, poncirin, prunin, and naringenin) by paper chromatography, and measuring their fluorescence intensities. A newly formulated benzene-acetic acid-water-nitromethane solvent has given good results when employed in the paper chromatography. Polyamid or Polyclar AT columns appear to be promising tools for separating many of the constituents of grapefruit juice. Pure poncirin for use as a standard has been prepared from extracts of trifoliate oranges; and early and midseason Ruby Red grapefruit (1963-64 season) have been frozen for future use. Major effort will continue on quantitatively separating and determining the individual flavanones. (S3 2-39 (C) (Rev.)).

A new project has recently been initiated for investigation of the identities, quantities, and chemistry of components in Florida grapefruit.

responsible for excessive bitterness and harshness in processed products. Following exploratory experiments on a laboratory scale, pilot plant extraction of Florida grapefruit was begun, but difficulties encountered with the process led to resumption of work on a laboratory scale. Approximately 45 pounds of grapefruit have been extracted and the volumes reduced to a workable size for isolation and identification. Column chromatographic procedures, thin-layer chromatography, various colorimetric tests, and spectrophotometric procedures have been investigated for use in the isolation and identification of flavonoids in grapefruit extracts. (S3 2-42).

3. Factors Affecting the Physical Characteristics of Processed Citrus Products. Much of the flavor of citrus is due to incorporation of peel oil into the juice, evidently--as shown by recent work--by its being dissolved in suspended lipids. This finding may explain the observations that the flavor of the juice changes upon standing and that an increase of suspended solids, within limits, improves its flavor. Examination of "cloud" fractions from additional samples of orange juice confirmed the previous conclusion that juice from freeze-damaged fruit contained a higher percentage of solvent-insoluble solids than did normal juice. Because a severe freeze rendered material collected from oranges during the 1962-63 season atypical, additional samples of cloud were collected from early and midseason oranges of the 1963-64 season. Analyses for lipids, carbohydrates, ash, and nitrogen have not revealed important differences associated with season or variety during the past two years. However, differences between pulp and fine cloud and between suspensions prepared from different parts of the fruit indicate that source of cloud is important. The natural cloud (very fine particles), which contains much of the orange flavor, appears to come from the juice rather than from mechanical disintegration of structural tissue. Attempts to separate cloud components by gel filtration or by application of electric potential to suspended cloud proved ineffective. Plans have been made for collection, processing, and analysis of samples of juice, pulp washings, and centrifuge sludge during the Valencia season for comparison with previous seasons' samples. The project for investigation of the chemical and physical nature of components of cloud has been revised, based on research results to date. (S3 2-38) (Rev.)).

4. Basic Investigations of Carotenoids in Grapefruit. Fundamental studies of the nature and mechanism of the biosynthesis of carotenoids support the theory of parallel synthesis of the carotenes. Data obtained from labeling tomatoes with $C^{14}O_2$ and 2- C^{14} -mevalonic acid indicate that although phytoene may be a precursor for other carotenes, including lycopene, it is probably not a pool precursor. As an extension of this basic work, the effects of the environmental factors of temperature and light on the pigments of red grapefruit are being evaluated. On-the-tree experiments with red grapefruit showed that cold temperatures (60° F days, 40° F nights) caused degreening of the fruit, cessation of growth, and a decline in lycopene content, whereas fruit at high temperatures (95° F days, 85° F nights) remained green, continued to grow, and retained high lycopene content despite rapid sizing. When grapefruit attached to a tree were exposed to labeled carbon dioxide,

the amount of label in the carpels 48 hours after exposure was about the same whether the fruit was exposed in the light or in the dark. However, label in the peel was about 30-50 times higher after light exposure than after dark exposure, since in the light very active photosynthesis fixes CO_2 before it diffuses through the peel. Photosynthesis and photosynthetic efficiency (CO_2 fixed per mg. chlorophyll) reach a minimum approximately when lycopene concentration reaches a maximum. The carpels then appear capable of total synthesis of carotenes; there is little probability of precursors from leaves or stems playing a major role in carotene synthesis within the fruit. The evidence that temperature is a major factor is the first indication that anything outside the fruit can influence the concentration of lycopene on the inside. Such information, together with the biochemical data, may introduce a new theory of biosynthesis, determine optimum harvesting time, and ultimately permit control of color in the fruit. Future plans include an investigation of noncarotenoid lipids having chromatographic behavior similar to that of the carotenes. (S3 2-34 (Rev.)).

B. New and Improved Food Products

Development of New Grapefruit Based Beverages. Research is continuing on the utilization of natural and debittered grapefruit juice in improved juice drinks. Preliminary work on resin debittering by use of nylon, Polyamid, or Polyclar AT powders appears promising. It has been shown that resin debittering does not materially change the flavor or composition of the juice, other than to remove bitter constituents, and does not adversely affect the vitamin C content. Resins having greater specific absorption capacities for flavanones are being sought; if they can be found, resin debittering offers an alternative process to use of enzymes. Work to develop accurate tests for bitterness in grapefruit juice and blended drinks will be aided by recent progress on purification of needed flavanones. Completed flavor and color evaluations of grapefruit-strawberry drink concentrates stored 12 months in plain and enamel cans showed that samples in plain tin cans retained acceptable quality for seven months at 68° F, or lower, but frozen storage is necessary if maximum flavor and color are to be retained for as long as a year. The drink is now ready for consumer acceptance testing. Future plans are to purify the flavanones necessary for the development of better tests for bitterness, to evaluate other resins, to study the development and storage of flavonoids in grapefruit before maturity, and to evaluate other blends of grapefruit with fruit or berries. (S3 2-40).

C. New and Improved Processing Technology

Application of Foam-mat Drying to Florida Citrus. Investigations of factors affecting processing and product characteristics of foam-mat dried orange juice powder were continued in cooperation with WU and the Florida Citrus Commission. Foam having small and uniform bubble sizes has been formulated to permit reduction of moisture to less than 1% in the final powder without secondary desiccation processing. Achieving this lower

initial moisture content should make the process more economical, eliminate the need for an in-packing desiccant, and impart a higher degree of storage stability. The most useful release agents and best temperatures and pressures for the "warm-rolling" or "densitizing" treatment have been developed for increasing bulk density of orange powders without damaging organoleptic properties. The "warm-rolling" technique and packaging treatments including vacuum equilibration and use of CO₂ have resulted in improvements in reconstitution and appearance of the juice. In studies of the effect of brix/acid ratio on drying of orange powders, a definite taste preference was shown for powders made from concentrates with brix/acid ratio of 14/1. The addition of antioxidants to orange powders did not improve their storage life at 85° F. Thin-layer chromatography and column chromatography have indicated some relationship between certain carotenoid fractions and the development of off-flavors upon prolonged storage of orange powders at elevated temperatures. These analytical methods may lead to objective measures of storage stability, storage history, or quality. Plans include installation and testing of a crater-type foam-mat dryer, further improvement of reconstitution ease and appearance, determination of the relationship between conditions under which a concentrate is prepared and its drying characteristics, and comparison of freeze-dried with foam-mat dried powders. (S3 2-32; S3 2-43).

Storage tests on grapefruit powders prepared during time/temperature drying studies have been carried out in a continuation of the cooperative study conducted by SU, WU, and the Florida Citrus Commission. Stored as long as 12 weeks at 85° F and more than 16 weeks at 70° F the grapefruit powders have shown no significant change in flavor. Use of new foam formulations has reduced moisture content to less than 1% without employing drying temperatures greater than 180° F or a secondary drying process. This advance obviates the need for an in-package desiccant. In conjunction with the "warm-rolling" or densitizing treatment, recently developed CO₂ packaging treatments facilitate reconstitution and improve appearance of the reconstituted product, eliminating or retarding the appearance of the previously troublesome milky or foamy character. Several grapefruit powder samples have been evaluated for suitability for use in consumer acceptance tests in Western Germany. Future work will involve testing variables related to improved reconstitution and appearance and to stability on storage. (S3 2-41).

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UTILIZATION RESEARCH AND DEVELOPMENT
Processing and Products
Western Utilization Research and Development Division, ARS

Problem. The economic stability of the citrus and subtropical fruit industries in the Western Region is dependent upon effective utilization of fruit that cannot be accommodated on the fresh fruit market. The utilization of surplus or wholesome but blemished fruit provides the margin necessary to assure adequate returns to the farmer and continued development of stable markets. Ineffective utilization of products and continuously increasing processing costs are resulting in decreased returns to the growers. The California-Arizona grapefruit industry is encountering difficulty in disposing of both fresh fruit and processed grapefruit products. The pineapple and subtropical fruit industry in Hawaii must find practical methods for processing its products for export in order to prevent the accumulation of burdensome surpluses. The navel orange industry in California is hampered by the unavailability of satisfactory processes for the utilization of navel oranges. Juice extracted from early fruit, and during some seasons from almost all of the navel oranges, contains unknown substances that impart an intolerable bitter flavor to juice products after mild heat-processing or after standing at ambient temperature for a short time. Large new plantings of navel oranges may be expected to aggravate the utilization problem. Deterioration of the flavor and color of these and other processed citrus and subtropical fruit products imposes severe limitations upon the economic stability of the industry.

Information is needed on the chemical composition of citrus and subtropical fruits and their products and byproducts as a basis for the development or application of new and improved methods of processing; and for the production of new and improved food and industrial products and pharmaceuticals. Special attention needs to be given to the nature of the chemical changes involved during pre-treatment, processing and handling which lead to the formation of off-flavors, -colors, and -odors in processed products.

USDA AND COOPERATIVE PROGRAM

In the Western Utilization Research and Development Division, a concentrated program of fundamental research on citrus and subtropical fruit and its application to industry problems is conducted at the Division headquarters at Albany, California; at the Fruit and Vegetable Chemistry Laboratory in Pasadena, California; at the University of Hawaii, Honolulu; by contract at Tucson, Arizona; and, under a P.L. 480 grant, in Bogota, Colombia. Investigations are conducted on the composition of citrus essential oils, flavonoid compounds and other citrus constituents that are related to off-flavors and darkening of citrus products, the natural flavor components of oranges, enzyme systems that are involved in the appearance and disappearance of constituents and structures of plant tissues, constituents of dates that affect the quality and stability of products, and the application of findings of such research to the development of new and improved citrus, tropical, and subtropical fruit products.

The Federal program of research in this area totals 20.7 professional man-years, including contract research equivalent to about 0.4 professional man-year per year and one scientist whose salary is provided under Memorandum of Understanding by the Lemon Products Technical Committee. Of the total, 14.3 are assigned to investigations on chemical composition and physical properties and 6.4 on new and improved food products and processing technology. In addition, the Division supervises a research project on the development of new tropical fruit products supported by a P.L. 480 grant.

PROGRAM OF STATE EXPERIMENT STATIONS

The states are engaged in research on the utilization of citrus and subtropical fruits in an effort to expand markets through increased use. Research on citrus begins with efforts to reduce decay during storage and transit through control of the physical, biochemical and physiological changes in citrus during handling--i.e., the effects of precooling and study of factors of temperature, humidity and air flow during cooling.

New product studies involve determination of the basic product characteristics, flavors, types and components and relate these to market demands. A thorough examination of the sources of flavor of some common foods including citrus is in progress. A phase of this program deals with the effects of oxidation and/or hydration on the flavor and aroma of the terpenes of citrus and the role structure plays in odor production. Conversion of citrus terpenes to useful chemical compounds is also under study. Another study has as its goal to extract, separate, identify and determine quantitatively each of the volatile components responsible for the natural flavors and occasional off-flavors in citrus fruits, citrus oils and processed citrus products.

The characteristics of commercial frozen Florida orange concentrate and superconcentrate are frequently determined to establish physical and chemical characteristics of the products. Base juices are prepared from citrus fruits and used to determine the effects of the fruit components on the characteristics of frozen citrus concentrate.

Firming of canned grapefruit sections with calcium salts and other materials is also under study. Characteristics of canned and concentrated juices are determined initially and after storage at elevated temperatures.

Utilization of citrus waste is receiving attention. In one study, isolated cultures from natural sources are being used to investigate production of glycerol and glycols from citrus wastes by fermentation.

The program with other subtropical crops such as guava, mango, soursap, banana, pineapple, coffee, and plantain includes production of freeze-dried products of high quality and good storage life. The economic feasibility of expanding markets for subtropical agricultural products through processing and utilization of new products is being further tested by preparation

of soft drinks from tropical fruits--carbonated and non-carbonated, canned and bottled. Basic biochemical and microbiological studies of tropical foods are directed to discovery of special methods, special properties or nutritional qualities which may be used in new product development. Production of such products as banana purée, fried snack items, flakes, flours, fruit powders, flavoring extracts, candied items, canning syrups, nectars and juices is under study.

In addition, attempts to isolate the enzymes of fig latex are underway. The isolated proteolytic enzymes are characterized as to molecular weight, activity and amino acid composition.

Two stations, Hawaii and Puerto Rico have programs designed to improve the economic condition of their coffee industries. These researches embrace work on the microbiology of the coffee fermentation process, on the drying of coffee, and on the quality and acceptability of the final product.

The total research effort in citrus and subtropical fruit is about 21.6 professional man years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Citrus Composition. The quality and stability of citrus products are determined by the chemical components and physical properties of the fruits from which they are made. Research is continuing on composition of grapefruit, cold pressed lemon oil, and lemon juice concentrate. Research on lemons is supported in part by the Lemon Products Technical Committee which pays the salaries of two research fellows at the Pasadena Laboratory. Research on grapefruit oil disclosed the presence of a sesquiterpene ketone (nootkatone) at significant levels. This ketone appears to be an important factor in grapefruit flavor. Threshold levels of nootkatone for taste detection in a sucrose solution were determined organoleptically to be around 100th of the normal concentration of the compound in high flavor quality grapefruit oil. Nootkatone was found in the peel oil-free juice at about the threshold level. The compound was also found in other citrus oils but in lower concentration.

Improved chromatographic procedures confirmed the presence of two sesquiterpenes earlier reported in lemon oil (beta-bisabolene and alpha-bergamotene) and also indicated the presence of caryophyllene and five sesquiterpenes in minor amounts. Studies of the amounts and identities of the carotenoid pigments of lemon peel and pulp at various stages of maturity and lemon leaves and frozen juice concentrate were completed. These substances contribute to the color and nutritive qualities of lemon products. Each of these sources contained at least 20 individual pigments although there were major differences in the pattern of pigments from each source. Lemon peel contained higher percentages of violaxanthin and zeta-carotene and smaller

percentage of cryptoxanthin than did the pulp. The pulp also contained several carotenoids not present in the peel. Beta-carotene was the major carotenoid of frozen juice concentrate. The yellow color of ripe lemon peel is due to the small amount of carotenoids and the light color of the major carotenoids. The major carotenoids of green lemon peel and leaves are those usually associated with photosynthetic tissues.

A study on the effects of climate and growing area on the composition of lemons is continuing in order to determine the range of natural variation in composition over several growing seasons. The completed data will be useful in improving the accuracy of previously developed analytical methods coupled with multiple regression analysis for determining the authenticity of lemon juice and useful to growers and processors in defining factors influencing fruit composition. Individual polyphenolic compounds of lemon juice are being isolated, identified, and their concentration determined.

Carotenoid pigments of desert grapefruit, Marsh seedless and Ruby Red, are under intensive study. Late season fading of red from Ruby Red grapefruit pulp was found connected with the formation of beta-carotene and its diepoxide at the expense of lycopene. Phytoene is one of the major carotenoids in the Ruby Red grapefruit but is not present in detectible amounts in the Marsh variety. As grapefruit ripens, green chlorophyll disappears and the carotenoid pattern of both peel and pulp changes significantly. The carotenoid mixture in peel is extremely complex. A total of 23 individual components were found in the peel of green Marsh seedless grapefruit and a total of 34 components in the peel of ripe fruit. During ripening major changes in relative concentration of important carotenoid constituents took place. Studies were initiated on steroids and coumarins of desert grapefruit. Isolation and accumulation of individual compounds of these types will be made for identification and tests of biological activity.

2. Bitter Constituents of Citrus. Several classes of compounds that are natural constituents of oranges and grapefruit impart bitter flavor. During processing and in subsequent handling and storage, changes may occur in individual components that affect quality of product. A clear understanding of the chemistry of these compounds is a first step toward improvement in products and processes. A number of carbon-linked flavonoid glycosides were isolated from citrus fruits and the structure of one of them (vitexin) has been elucidated. It will help clarify the chemistry of the entire group. An important disaccharide (neo-hesperidose) was synthesized. This compound is responsible for extreme bitterness or sweetness when it exists linked to certain flavonoids. The synthesis of neo-hesperidose has proved correct a structure previously hypothesized from degradative methods. Furthermore, it will make possible preparation of this disaccharide or its glycosides in radioactive form for metabolic studies.

The bitter flavonoids neohesperidin and naringin were previously converted to dihydrochalcones that are sweet enough to be considered as commercial

sweeteners. Neohesperidin has now been synthesized from readily available commercial chemicals. The synthetic pathway used has been adapted to other syntheses and new flavonoids are being constructed in the laboratory and evaluated for bitterness and sweetness in a search for still better compounds that might be used as low calorie sweeteners for food.

Limonoid compounds responsible for the bitterness of navel oranges are being isolated and identified. A new bitter principle was isolated in pure form from several citrus fruits and its structure established by infrared and nuclear magnetic resonance spectra and by chemical conversions. The new compound (deacetylnomilin) is closely related to obacunone and nomilin which are intermediates in the formation of the established bitter principle, limonin. The new bitter principle can be converted by acetylation to obacunone and nomilin. Thus these three compounds constitute a pool of interconvertible metabolites which exhibits different bitterness depending upon the relative amounts of each as they exist in navel orange juice at any particular time. Larger quantities of the new bitter principle are being isolated for more detailed study.

3. Pharmacological Investigations of Citrus Products. The dihydrochalcones of bitter neohesperidin and naringin from citrus are intensely sweet and are potentially useful as low calorie sweeteners of food products and for use in sugar-free diets. Ninety-day feeding tests of rats were concluded, indicating no obvious toxicity at levels of ingestion up to 200 times the level calculated to be equivalent to the sweetening provided by the average daily sucrose consumption in man in the United States. The rats used in the 90-day feeding tests were also used for a reproduction assay. The safety of these compounds for use by man will depend upon the absence of unfavorable histopathological findings.

4. Fruit Flavor Components. Gas-liquid chromatography continues the rapid advance of the past several years and continues to expand its usefulness in study of the chemistry of volatile natural components. Information was obtained on relative efficiency of capillary columns attached to hydrogen flame ionization detectors and attached directly to the mass spectrometer. Operation with the end of the column at the mass spectrometer vacuum did not reduce efficiency. Large bore capillary columns and packed columns with high efficiency and a low pressure-drop were developed to prepare pure samples of compounds heretofore very difficult to isolate. Spectral data in addition to mass spectra are useful to establish chemical structure of difficult compounds and mixtures. Milligram quantities of pure material must be isolated to observe and measure such spectra and these new highly efficient columns will help prepare such samples. Larger samples are also required for essential taste testing of the odor contribution of the individual compounds.

Evidence is accumulating that the more important characteristic aroma-bearing compounds of oranges are oxygenated compounds which boil well above 100° C. Earlier chromatographic systems did not separate high boiling mixtures well. The new packed columns with low pressure-drop are already proving to be extremely useful particularly in recovering material for nuclear

magnetic resonance analyses. Computer analysis of nuclear magnetic resonance data can draw a conclusive spectrum from much smaller samples. It was this reduction in sample requirement combined with the large bore capillary and low pressure-drop chromatographic columns that allowed substantial advances in the separation of high boiling oxygenated compounds from orange oil.

5. Composition of Dates. Utilization research on dates is conducted with industry support by means of a fellowship provided by the Date Administrative Committee cooperating under a Federal Marketing Order. In compositional studies related to discoloration of dates and date products, dactylifric acid was found to be one of the main enzymatic browning substrates. Isolation, structural determination, and synthesis proved for the first time the existence in nature of a new family of compounds, the substituted cinnamoyl shikimic acids. Knowledge of these new compounds opens the way for more detailed studies of the browning mechanism of dates. The identification of dactylifric acids may be important to the biochemistry of plants in general because of the importance of shikimic acid in the biosynthesis of aromatic compounds such as tyrosine, phenylalanine, substituted cinnamic acids, flavonoids, coumarins, and lignin. Isodactylifric acid, an isomer of dactylifric acid, was isolated from dates in pure crystalline form and its structure determined. This compound also has proven to be an important enzymic browning substrate.

B. New and Improved Food Products and Processing Technology

1. Citrus Products. Large quantities of the sweet compounds naringin dihydrochalcone, and neohesperidin dihydrochalcone were prepared from citrus byproducts and found to have no obvious toxicity to rats in 90-day feeding tests at levels of ingestion up to 200 times the sweetening provided by the average sucrose consumption of a man in the United States. If research evidence confirms the safety of these intensely sweet compounds they may find use in dietetic foods and soft drinks and as sweeteners for diabetics. The compounds are up to 20 times as sweet as saccharin and are free from the bitterness of saccharin. Considerable commercial interest has been expressed in the sweeteners. Tests by one company indicate that sweetness from these compounds is relatively slow to develop in the front part of the mouth as when used in coffee, for example. The company believed they would serve better in chewing gum where the sweetness may take longer to develop in the back part of the throat. The conversion of naringin into new flavanones and dihydrochalcones will continue with the emphasis on developing new sweeteners that sweeten faster and in the front part of the mouth.

Studies were continued on the effect of growing area, culture, and processing on lemon juice composition in order to be able to identify the natural product. Commercially feasible variations in processing did not alter composition appreciably. Citric acid content of various juices calculated using the multiple regression equation reported last year agreed quite well with the titrated acidity for each processing variable. Knowledge on

natural variations in the composition of lemons is accumulating and will improve the reliability of recently developed methods for characterizing juice products, and will define for growers and processors the factors which influence the composition of lemons.

2. Date Products. Research and development on improved date products are supported in part by the Date Administrative Committee operating under a Federal Marketing Order. Texture improvements by a controlled heat process were reported last year and have become widely used in date packing. Heat and moisture activation of natural date enzymes results in sucrose inversion, increased tenderness, and improved quality, and inhibits the tendency of dates to dry out during storage.

Other factors important in the quality of date products are under continuing investigation. A tendency of dates to turn dark during storage can be inhibited by protecting the dates from oxygen. Studies on the flavor of processed dates and flavor changes which occur during processing were initiated. In commercial experience some lots of processed dates taste better than others, but no one knows why. We suspect that the more acid dates have more flavor and are making progress on modified processes that increase acidity of dates. Preliminary observations indicate that flavor enhancement is associated with, but not necessarily dependent, upon increased acidity. Studies on flavor development and enhancement in processed dates will continue.

3. Tropical Fruit Products. The field station established in Honolulu last year in cooperation with the Hawaii Agricultural Experiment Station has initiated research on bulk- and weight-reduction of tropical fruits to yield high-quality products that ship well for export to the mainland or foreign countries. A Department scientist was transferred to the new station and new laboratory facilities were provided. A preliminary exploration of processing properties of a variety of Hawaiian-grown tropical fruits was conducted. Juices and purées were prepared from guava, papaya, passion fruit, pineapple, and jaboticaba. Heat treatments are being sought to inhibit the strong gelling of guava and papaya. Flavor investigations were initiated to determine the differences between freshly pressed pineapple juice and the canned pineapple juice that is widely known and accepted. Characterization of the carotenoid pigments that color guavas pink is under investigation. Effects of drying rates on product color of dehydrated products from different varieties of bananas were also initiated. Improved means for retention or restoration of the flavor and color qualities of tropical fruit products will continue.

Research on stabilization of flavor concentrates of tropical fruits was initiated at the Institute of Technological Investigations in Bogota, Colombia, under P.L. 480 funds. Equipment was obtained for pilot extraction and concentration of juice and for laboratory analysis.

4. Foam-mat Drying. Cooperative research with the Southern Utilization Research Division is conducted on the foam-mat drying of orange and other citrus products at Winter Haven, Florida. Informal cooperation continues with industry representatives who are interested in commercial application of foam-mat drying. Commercial production of foam-mat dried lemon juice without added sugar is underway in California.

Improvement in foaming procedure allowed a longer beating time under conditions that do not destroy the foam and resulted in the drying of orange concentrate to 1% moisture content or less. Such low moisture content allows packaging and long-term room temperature storage without the use of in-package desiccants for dried orange products. The powder can be packed more tightly by pressing it through warm rollers. Improved release agents were found that prevent the powder from sticking on the warm rolls. Incorporation of homogenized and heat stabilized orange peel with orange juice concentrate and a small amount of sugar (5% of solids) yielded a high flavor quality foam-mat dried orange juice without the "locked-in" peel oil for flavor fortification.

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New and Improved Food Products and Processing Technology

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NUTRITION AND CONSUMER USE RESEARCH

Consumer and Food Economics Research Division, ARS
Human Nutrition Research Division, ARS

Problem. The assortment and characteristics of foods available to consumers are constantly changing with the adoption of new production, processing, and marketing practices. Constantly changing also, as nutrition science advances, is our understanding of the nutritional needs of man and the manner in which these needs can best be met by food. To help meet the Department's responsibility to advise consumers on the quantity and variety of foods that will assure maximum benefit and satisfaction, research must continue on the nutritional requirements of persons of all age groups, and on the nutrient and other values of foods and on how to conserve or enhance these values in household preparation and processing. Periodic surveys of the kinds and amounts of foods consumed by different population groups and individuals also are essential for evaluation of the nutritional adequacy of diets and to give the guidance needed for effective programs in nutrition education. Information from such surveys provides assistance needed in market analyses for different commodities and in the development and evaluation of agricultural policies relating to food production, distribution, and consumer use.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program of research concerned with (1) Nutritive and other consumer values of raw and processed foods as measured by chemical or physical means and by biologic response; (2) effects of household practices upon the nutritive values and inherent qualities of foods, and the development of principles and improved procedures for household food preparation, care, and preservation; (3) surveys of kinds, amounts, and costs of foods consumed by different population groups and the nutritional appraisal of diets and food supplies; and (4) development of guidance materials for nutrition programs.

The research is carried out by two divisions of the Agricultural Research Service -- the Human Nutrition and the Consumer and Food Economics Research Divisions. Most of the work is done at Beltsville and Hyattsville, Maryland; some is done under cooperative or contract arrangements with State Experiment Stations, universities, medical schools, and industry. The total Federal scientific effort devoted to research in these areas totals 63.3 man-years. It is estimated that approximately 2.6 man-years are concerned with studies related to citrus and subtropical fruit products.

Human metabolic studies and the related exploratory and confirmatory studies with experimental animals and microorganisms concerned with defining human requirements for nutrients and foods are not reported on a commodity basis, though some of the work is applicable to this report. This basic nutrition research represents a total Federal effort of 26.7 professional man-years and is described in detail in the report of the Human Nutrition Research Division.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

Nutrient Value of Food

Food composition and nutritive value is most frequently related to indigenous agricultural products. Specific and locally grown raw products are being extensively evaluated for essential nutrients, especially in Hawaii and Puerto Rico. Much work is related to changes induced by growing practices, processing and storage.

Certain raw products are being evaluated for their significant vitamin contribution to nutrition. The effect of production and processing practices on vitamin content continues as an area of interest. Additionally, research has been directed toward the study of vitamins in foodstuffs as affected by inhibitory and stimulatory factors.

The total program in this area includes 36 projects in 23 States and is comprised of 23.4 professional man-years.

Properties Related to Quality and Consumer Use of Food

In the area of food preparation, products are related to quality by some measure. Special measures characterize certain classes of products; i.e., vitamin assays, enzymatic activity, water binding capacity, and changes in structural tissues. Combinations of these are involved in the quality evaluation work reported.

Comparative studies are being carried out on fruits and vegetables processed by freezing, canning and irradiation.

Food preparation research focusing on products for home use include: Microwave preparation of meats, fruits and vegetables, including the chemical alterations involved; and flavor characterization in frozen and stored products by means of vapor component identification.

This portion of the program includes 52 projects in 21 States and is comprised of approximately 50.1 professional man-years. This is a partial report of the State Experiment Station programs in food science and includes work undertaken by home economics departments. For research on food and fiber utilization see reports of the Utilization Research and Development Divisions.

Food Consumption and Diet Appraisal

The State program in food consumption and dietary appraisal extends the work of the Department to other segments of the population or to geographic areas not separately identified in the nationwide studies. Currently 12 States are contributing to this program. One regional project is designed to yield information regarding food purchase and consumption patterns of families with preschool children. Food habits will be evaluated in terms of the children's dietary needs. This research will provide information useful to both consumer and market interests. In the Western Region ongoing research on consumer satisfaction with selected fruits and vegetables is nearing completion.

The State program in this area totals 22.2 professional man-years.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Nutrient Value of Citrus and Subtropical Fruit

1. Tables of food composition. Research for the newly revised Agriculture Handbook No. 8 "Composition of Foods...raw, processed, prepared" has been supplemented by further research during the year and adapted to the needs of special projects.

Supplementary information on citrus fruit and an explanation of the procedures for deriving ascorbic acid values for citrus fruit that were published in the Handbook have been presented in a journal article and several talks. The derivation of these values serves to illustrate the kind of information needed to develop data for the Handbook; further it serves as a basis for determining appropriate applications and stating the limitations of the data. The search of the literature revealed a wide variation in the amount of ascorbic acid occurring in the different samples of any one kind of citrus fruit. Analysis of this array of values indicated that the principal determinants of the level of ascorbic acid in oranges were variety, site of production and period of picking within the harvest season. Statistics on production and marketing of commercial varieties were used to obtain a weighted value that could be used as nationwide, year-round average figure for ascorbic acid in oranges. In addition to this average, values were derived for different commercially important varieties of oranges, both

Florida and California, and values for canned, frozen, and dehydrated orange juice products. The article also provides additional detail for other kinds of citrus fruits, including seasonal changes in ascorbic acid in pink and white grapefruit, in tangerines, and tangelos. Problems in deriving representative vitamin A values for citrus fruits and their products on the basis of data currently available are also discussed in the article.

Formulas and procedures that were used in calculating the nutritive values of 250 food items commonly prepared at home are being summarized in a publication for special users, particularly therapeutic dietitians and medical research workers. A table showing average adjustments for vitamin losses during cooking has been developed and will be included in the publication.

Selected data from revised Handbook No. 8 have been made available in decks of punched cards and magnetic tape for research workers. Available in these forms are the data from Table 1, the nutritive values for 100 grams edible portion of the foods; from Table 2, nutritive values for one pound of food as purchased; from Table 3, selected fatty acids in foods.

Tables for the Department of Defense have been prepared on the composition of 630 food items procured by the Defense Supply Agency for feeding military personnel. Values for the composition of foods developed for Handbook No. 8 and many additional values provided by the Department of Defense were used to develop the data needed for the numerous special food products meeting military specifications.

2. Vitamins. Analyses for the vitamin B₆ content and distribution in a variety of foods including citrus, subtropical, and other fruits available to and as eaten by consumers are nearly completed. Manuscripts are in preparation. Analyses on meats and vegetables are in progress.

A fluorometric procedure for the determination of pyridoxine as pyridoxal cyanohydrin was developed. The reactions were quantitatively reproducible over a range in concentration of 1 millimicrogram to 1 microgram per milliliter. Procedures for chemical assay for pyridoxal and pyridoxamine previously had been developed in this laboratory. Present studies are to adapt chemical procedures to analyze food extracts for the three forms of vitamin B₆. The procedures are expected to provide a more constantly reliable method for measuring this vitamin. Values from the chemical procedures are being compared with values obtained by microbiological determinations for vitamin B₆ in foods.

Development of coordinated procedures for B-vitamin analyses continued with emphasis on a rapid, stable chemical method for nicotinic acid.

3. Mineral elements. Laboratory analyses for mineral element content of 29 fresh and 6 dried fruits were completed and statistical analyses are in progress. Results presently available indicate that sodium as well as aluminum, boron, copper, iron, and manganese occur in minor amounts in fruits. The mineral element content of the fruits varied within and among production areas. All mineral elements were not equally affected. Lot-to-lot variation of avocado, blackberries, and fresh apricots was significant for seven of the ten elements analyzed. In tangerines, only sodium content varied significantly. Papayas and limes were uniform in mineral content. A manuscript giving details will be prepared.

4. Carbohydrates. Research is continuing on improving methods for analyses of individual sugars and applying them to various foods. Studies are concerned with extraction procedures, the determination of total and reducing sugars by conventional methods, and glucose and fructose by differential oxidation. Thin layer chromatography has been used for the separation and identification of some individual sugars from fruit and vegetable extracts.

Total and reducing sugars, sucrose, dextrin, and starch content of dry fat-free solids of composites representing 14-day diets for 16- to 19-year old boys were determined. The diets were based on USDA food plans at moderate cost. Variations among, and correlation coefficients between, different carbohydrate fractions were calculated. Sucrose content varied more than any other carbohydrate constituent. Variations among other carbohydrate constituents were not considered to be nutritionally important.

B. Properties Related to Quality and Consumer Use of Citrus and Subtropical Fruit

1. Constituents in cells and cell walls of fruits related to texture.

Research was initiated to obtain microscopic and histochemical information concerning the constituents of cells and cell walls in fresh and frozen fruits and their possible influence on texture of fruit varieties. Greater knowledge of minor constituents, such as lipids and proteins, and their relation to major polysaccharide constituents would lead to more informed selection of varieties and improvement in methods for freezing to retain a firm, yet tender texture of the fruit.

2. Food distribution program. Revision of the publication "Quantity Recipes for Type A School Lunches" (PA 631), was completed in cooperation with the Agricultural Marketing Service and the Fish and Wildlife Service, U. S. Department of Interior. This recipecard file provides 324 quantity recipes or variations and other information needed in preparing Type A lunches in schools participating in the National School Lunch Program. Recommendations on preparing, storing, and handling a wide variety of fruit, vegetable, cereal, dairy, meat, and poultry products were updated to take into account recent research findings and technology. New recipes were tested and evaluated, and all formulas and yields were recalculated in line with the 1964 revision of PA-270, Food Buying Guide for Type A School Lunches.

C. Food Consumption and Diet Appraisal

1. Planning for proposed nationwide survey, households and individuals.

A nationwide survey of household food consumption and of the food intake of individuals is scheduled for 1965. Plans have been developed for a survey that would provide at least 6,000 household schedules and 10,000 individual schedules in the spring of the year with smaller household samples in each of the three succeeding seasons. The information on the week's food use to be obtained from each household is similar to that obtained in 1955, except that information on home baking practices will not be requested and information requested on home food production, home canning and home freezing will be reduced to allow interview time for questions on the food intake of individual members of households.

In preparation for the proposed first nationwide survey of the food intake of individuals, data obtained by recall on the 1-day intake of food from nearly 550 individuals of all ages in Washington, D. C. during June and July 1963, have been studied in relation to two controversial issues that concern collection of data. The survey findings indicate that for this group: (1) The nonresponse rate on food intakes from individuals is not influenced by taking a schedule on household food consumption first in comparison to taking none, nor is it influenced by taking a schedule on food intakes from half in comparison to all individuals in the family; and (2) homemakers report the amounts of food eaten by family members in terms of their individual servings far more often than as proportions of household amounts. Tabulations of the Washington data also are useful as a pretest for tabulation of the nationwide survey.

2. Effects of food distribution programs on diets of needy families.

A survey of the food consumption of more than 800 households that were not participating in the food stamp program in St. Louis was made in May and June 1964 to determine the relation between usual family food expenditures and payments required for food coupons. Homemakers were asked also why their families did not participate in the program. Results of the analysis will guide the Department in revamping the St. Louis stamp program to make it more acceptable to eligible families and yet keep it within the limits of the program. Because of interest in the nutritional quality of food consumed by low-income families, an assessment may be made later of the dietary levels of these families. This is the sixth in a series of USDA food program surveys made in cooperation with the Marketing Research Division, ERS to assist the AMS to administer the food stamp and direct distribution programs.

3. Food consumption of the rural population in Spain (P.L. 480 research).

A survey of the food consumption of the rural population in Spain has been initiated by the Spanish Ministry of Commerce under the cooperative sponsorship of the Economic Research Service and the Agricultural Research Service, using P.L. 480 funds. The study will provide information needed in

appraising potential markets in Spain for U. S. farm products and should yield information useful to U. S. authorities on efficient ways of improving nutrition in low-income areas. The Spanish Ministry of Commerce expects to obtain much useful information on which to base a program for improving the diets of rural families, especially through better distribution of food. Information on food consumption, income levels, and related socio-economic characteristics has been obtained from about 1,200 rural families in 6 major regions of Spain. In summarizing the results, emphasis is being placed on (1) determining the nutritional shortages among these rural families at different income levels in the different regions, and (2) computing income elasticities for different foods as well as total food consumption.

4. Effect of socio-economic factors on food intakes of individuals. Under a cooperative agreement with the Minnesota Agricultural Experiment Station intensive analysis of data previously collected showed that: (1) Intakes of vitamins A and C from food by 9- to 11-year-old Ohio children increased with family income, (2) at each income level, a larger proportion of urban than farm children had food that provided recommended amounts of vitamins A and C, and (3) that children whose food was supplemented by vitamin A and C concentrates in general did not need them as they were in "nutrition conscious" families that provided the children with foods that were high in these nutrients.

5. Nutritive value of national food supply. The nutritive content of the per capita food supply is calculated each year from estimates of quantities of foods consumed (retail weight basis) as developed by the Economic Research Service. This series, which begins with the year 1909, is being completely revised to incorporate newest estimates of per capita consumption, revised food composition data from Agriculture Handbook No. 8, and new information on the nutrients added to foods by enrichment and fortification.

A survey conducted by the Bureau of the Census for the Consumer and Food Economics Research Division has provided information for the years 1957-61, on quantities of enrichment ingredients supplied to processors to fortify flour and cereal products. Through this program about one-third more thiamine, one-fifth more iron and niacin, and one-tenth more riboflavin are added to the Nation's diet than would be available if foods were not enriched.

For the first time, the enrichment survey was extended to include information on the quantities of ascorbic acid and vitamins A and D added to foods, thus furnishing a base line for future surveys. Currently the amount of ascorbic acid added to foods would be enough to increase the level in the per capita food supply by 5 percent. The contribution from synthetic vitamin A is 7 percent of which 6 percent is added through margarine. Vitamin D is not at present included in nutrient estimates.

6. Household practices in home freezer management. Recording forms and questionnaires for obtaining data on management practices of urban and rural home freezer owners were pretested and necessary revisions were made in preparation for data collection among households in Fort Wayne, Ind., and a nearby rural area. Information will be obtained in two seasons on the kinds, amounts, sources, prices, and turnover rates of frozen foods stored in the home. Such data will provide information needed to develop guidance materials for improved management of home freezers.

7. Development of food budgets and other basic data for food and nutrition programs. Interpretation of nutrition research findings and their application to practical problems has continued as part of an ongoing program to assist nutritionists, teachers, health workers, and other leaders concerned with applied nutrition programs or nutrition policies. Information developed under this program is provided to many groups both within and outside the Department working on practical food programs, on questions relating to nutritional requirements, food consumption, nutritional importance of specified foods, and on nutrition education. Increased emphasis has been given this year to opportunities for disseminating information to the public through TV and radio, the press, conferences, workshops, and the Department's Food and Home Fair.

Food budgets at different cost levels for individuals and families are priced quarterly for publication in Family Economics Review as a continuing service to welfare workers, extension agents, and others needing this information. For example, in June 1964, the cost of one week's food for a family of four including 2 school-aged children, was estimated to be \$24.40, \$32.80, and \$37.40, respectively, for the low-cost, moderate-cost, and liberal plans.

The food budgets published in Home Economics Research Report 20, "Family Food Plans and Food Costs," have been reexamined in the light of revisions in food composition data (Handbook 8, revised) and in recommended dietary allowances of the National Research Council. Some modification in food quantities was needed for certain individuals. This has necessitated revision of food plans and their presentation in technical and popular publications, including Agriculture Handbook 16, "Planning Food for Institutions," now being readied for publication. The "Food Purchasing Guide for Group Feeding," formerly a part of Agriculture Handbook 16, is in the final stages of editing for publication as a separate handbook.

All other existing guidance materials for nutrition programs were reviewed in light of the changes in recommended dietary allowances and in food composition data. Some publications have been revised; others will be updated for the next reprinting.

Nutrition Program News, a bimonthly periodical prepared for members of State nutrition committees and other community nutrition workers provides one channel for disseminating pertinent information about Federal programs and for reporting nutrition activities in the States. Issues this year included such diverse subjects as a report of the World Food Congress held in Washington, June 1963, "Labels on food products--the protection they give," and "Nutritional fitness for teenagers." Assistance to workers in nutrition programs has been provided also through consultation and program participation by staff nutritionists.

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Properties Related to Quality and Consumer Use

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Food Consumption and Diet Appraisal

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III. MARKETING AND ECONOMIC RESEARCH

MARKET QUALITY

Market Quality Research Division, ARS

Problem. Research is needed to develop better objective indices for measurement of quality of citrus and other subtropical fruits. This would result in more meaningful grades and standards which could be better enforced. Instrumentation and automatic devices for quality sorting on a commercial basis might be possible. Decays and fruit soilage present serious problems in both domestic and export markets. Much research is needed to relate handling practices, packaging, precooling and transit refrigeration to wastage, and to develop effective treatments for decay reduction. There is a vast field for research on controlled atmosphere storage for oranges, grapefruit, and lemons. Problems which are sometimes distinct and sometimes interrelated exist in each of the geographical areas but which require biological research in the separate production areas for solution. Several species of common stored-product insects attack dried citrus pulp animal feed and may build up tremendous populations. In some cases wholesalers and retailers have refused to handle the product because the excessive insect infestation creates a hazard to other commodities in stock. There is an urgent need for effective preventive measures to be used in warehouses that will not leave hazardous residues in the feed, and for the development of packaging that will resist insect infestation of the product in marketing channels.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program involving largely applied research performed by horticulturists, plant physiologists, plant pathologists, and food technologists. The work is conducted in the producing areas of California, Florida and Texas. Market studies are made in Belle Mead, New Jersey and Chicago. P.L. 480 grants are operative for research in Colombia on avocado and papaya fruits; for studies in India on identification and mode of infection of fungi causing postharvest rots of tropical fruits; a project in Italy on X-ray detection and identification of incipient decays in citrus fruits; and in Spain on detection of additives in citrus juices. A contract study on citrus fruit quality as related to mechanical harvesting is just getting under way at the Citrus Experiment Station, Lake Alfred, Florida. Irradiation research was done in part with funds provided by the Atomic Energy Commission. Basic studies on objective measurement of maturity are being completed under contract by the California Agricultural Experiment Station at Riverside.

Total federal professional man-years devoted to this area is 10.6. Of this 2.4 is devoted to objective measurement of quality; 1.0 to quality maintenance in storage; 2.0 to quality maintenance during transportation; 1.0 to

postharvest physiology; 3.7 to postharvest disease control; and 0.5 to program leadership. P.L. 480 projects in this area involve \$64,145 equivalent over a 3-year period in Colombia; \$45,200 equivalent over a 5-year period in Italy; \$29,732 equivalent over a 5-year period in India; \$56,163 equivalent over a 4-year period in Spain; \$77,138 equivalent over a 5-year period in West Germany and a recently negotiated 5-year \$83,620 equivalent project in Israel.

Work terminated during this period included factors influencing the storage and shelf life of Florida Persian limes (MQ 2-40); ripening and storage of Florida mangos and avocados (MQ 2-46); controlled atmosphere storage of citrus fruit (MQ 2-48--replaced by related new project MQ 2-98); and control of anthracnose on avocados and mangos (MQ 2-68).

PROGRAM OF STATE EXPERIMENT STATIONS

Research concerning market quality of citrus and sub-tropical fruit involves 22 projects in 4 States including California, Florida, Hawaii, and Texas. Research in California is designed to obtain basic information regarding the physical, chemical, and physiological characteristics of citrus fruits as influenced by storage temperature and length of storage. Other California research is involved in determining fundamental information on the physical, biochemical, and physiological changes in citrus fruit which affect quality during harvesting, processing in the packinghouse, shipment, and marketing.

Researchers in Florida are trying to develop methods for separating citrus fruits of higher internal quality which could be used by packinghouses to improve the quality of the fresh fruit pack. They are also interested in the decay and physiological breakdown of citrus fruit when subjected to various conditions of temperature, humidity, and air flow during forced air precooling.

Research in Hawaii is aimed at determining the factors that contribute to the keeping quality of fruits and vegetables in relation to shipment and marketability following quarantine sterilization, and at developing the best methods of maintaining or improving the keeping quality or marketability of these commodities under the treatments found necessary to destroy insect larvae and eggs. Texas researchers are studying methods of maintaining quality of Texas grown avocados through the marketing channel.

Disease investigations include studies to reduce fruit and vegetable decays during storage, transit, and marketing by post-harvest applications of fungicides. Some of the diseases receiving attention in these investigations are melanose, scab, and brown rot of citrus; cachexia, erocortis, stubborn disease, vein enation, wood pocket, xyloporosis, and other virus or virus-like diseases of citrus; banana diseases in Hawaii; root rot and sun-blotch of avocados, and brown spot of passion fruit.

Total market quality research effort on citrus and sub-tropical fruit at the State stations is approximately 3.3 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement of quality

1. Relation of Physical Properties, Chemical Composition and Metabolic Activity to Market Quality. Losses in weight, volume and length during storage were observed on Florida-grown Hamlin and Valencia oranges and Marsh grapefruit. Losses were greater at 60° than 32° F., and were increased by degreening. Changes in chlorophyll content with treatment and maturity were satisfactorily followed with the light transmittance instrument.

Experiments conducted at Riverside under contract with specifically labeled sugars suggest that oxidative paths in juice vesicles may be decreasing with the progress of maturation. Alcoholic fermentation is a major metabolic path in all orange tissue and it becomes more important in the maturing vesicle. Decreases in sucrose synthesis, sucrose inversion and general sugar catabolism in various orange tissues occur during maturation of oranges. Metabolism of exogenous sugars occurs in very small pools, or reserves, during transport into the cells of orange tissues. The major changes in metabolism, so far noted, occur before the normal harvest period and so appear to have no practical application as maturity indices. The experimental work under contract has been completed and a report is being prepared. (MQ 3-20)

2. Aromatic Polynuclear Hydrocarbons in Horticultural Crops. A compound that may be anthracene has been found on 13 of 16 samples at about 0.1 to 1.0 parts per billion. Commercial sprays and waxes applied were not related to the amount of anthracene found. No carcinogenic or other 4- or more nucleated hydrocarbon has been detected by thin layer or gas chromatography techniques. (MQ 3-46)

3. The Detection of Additives in Citrus Juices. A study has been initiated in Spain under this P.L. 480 project on means of detecting adulterated citrus juice. As a first step, a very comprehensive study is being made on the kinds and amounts of natural constituents in orange juice. These include the various kinds of acids, sugars, ash constituents, and carotenoids. The relation of maturity to some of the constituents is also being made. (E25-AMS-6k)

B. Quality maintenance in storage

1. Ripening and Storage of Florida Mangos and Avocados. Optimum storage for most cold-tolerant varieties of avocados was 1 month at 40° F. The Lula variety frequently stored successfully for 2 months at this temperature.

Avocados of the West Indian strain and some varieties of other strains were cold intolerant with an optimum storage period of 2 weeks at 55°. Longer storage at 55° usually resulted in chilling injury and softening. The optimum ripening temperature for avocados was 60° to 75°, with 60° being best for eating quality.

Optimum storage for most mangos was 2 to 3 weeks at 55° F. Chilling injury was not evident at 55° and some varieties stored successfully at 50°. All mangos were affected by chilling injury when stored below 50°. The optimum ripening temperature for mangos was 70° to 75°. This work has been completed. (MQ 2-46)

2. Controlled Atmosphere Storage of Texas Grapefruit. Studies were resumed on storage of Texas red grapefruit in controlled atmospheres and air at 45° F. The best atmosphere for control of rind pitting, maintenance of good internal and external color, and retention of fresh flavor was 0.5 to 1% oxygen and 5% carbon dioxide. Decay was negligible at the end of 17 weeks' storage but severe in all lots after 7 additional days at 70°. (MQ 2-48 and MQ 2-98)

3. Postharvest Changes in Papayas. This P.L. 480 project in Colombia has confirmed recent results by the Hawaiian Experiment Station that papayas should be stored at 55° F. Lower temperatures previously recommended cause chilling injury. (S5-AMS-3)

C. Quality maintenance during transportation

1. Export Shipment of Florida Grapefruit. Simulated and accompanied export tests with Florida grapefruit resulted in recommendation of a 60° F. transit temperature during the period September to January, and 50° for the remainder of the season. Early and midseason ventilated shipment of waxed fruit proved satisfactory. The best pre- and post-transit storage temperatures were identical to the recommended transit temperatures. A sodium ortho phenylphenate (SOPP)-hexamine dip, followed by a wax treatment and the inclusion of two diphenyl pads in the container reduced decay, rind breakdown and shrivel during transit and market holding. Rough handling during loading and unloading contributed to losses during export. This work will be terminated when the report is completed. (MQ 2-74)

2. Thermal Conductivity in Florida Citrus Fruit. The thermal conductivity values for the juice vesicles of oranges and grapefruit are 3.0539 to 3.3720, whereas the thermal conductivity for the rind range from 1.3992 to 1.6416 BTU/hr/ft²/F°/in. The mean diffusivity value for whole oranges is 0.0051 sq. ft./hr. There is some indication that both moisture content and density have a slight influence in the thermal conductivity and diffusivity values. (MQ 2-53)

D. Postharvest disease control

1. Control of Decay of California Citrus Fruits. 2,6-dichloro-4-nitroaniline (DCNA) at pH 11.5 or higher and 110°-115° F. gave as good or slightly better control of Penicillium digitatum (green mold) infections in lemons than the standard sodium ortho phenylphenate (SOPP) treatment but was slightly less effective than the standard soda ash treatment.

Immersion in 130° F. water for 5 minutes or 125° water for 10 minutes gave satisfactory control of decay caused by P. digitatum on inland-grown summer lemons. Heat tolerance varied with season, geographic area, climatic conditions prior to harvest, length of time between picking and treating the fruit, and holding temperature before treatment. Hot water was not as effective as DCNA, SOPP, or soda ash at the same temperatures. (MQ 2-24)

2. Control of Postharvest Diseases of Florida Citrus Fruit. 2-aminobutane acetate effectively controlled decay on several varieties of oranges. Hot water treatment was less effective than a dip in 2-aminobutane solution but was equal or better for oranges than the standard SOPP-hexamine treatment. Hot water treatments were less effective with grapefruit and tangerines than with oranges. Increased decay of Valencia oranges following simulated mechanical harvesting was largely eliminated by prompt treatment with SOPP-hexamine. The date of artificial inoculation of oranges in the grove or the time of harvest had very little relation to development of stem-end rot after harvest. (MQ 2-65)

3. Irradiation for Control of Postharvest Diseases. Irradiation with gamma rays increased rind pitting of oranges without reducing decay during semi-commercial tests. Avocados and olives were severely discolored both internally and externally by radiation. This work will be terminated upon completion of the report. (MQ 2-82)

4. Control of Anthracnose on Mangos. As a result of previous research, equipment for hot-water treatment of mangos was installed in a commercial packing plant. Experience with fruit treated in this unit showed that a treatment for 5 minutes at 130° to 131° F. was effective for the retardation of anthracnose infections. Slight heat damage occasionally occurred on some varieties but was not of commercial importance. This work has been completed. (MQ 2-68)

5. Stylar-end Breakdown of Limes. Stylar-end breakdown, a physiological disorder of limes, was increased by dry-air heat treatments. The breakdown developed on all large mature limes exposed to temperatures of 110° to 115°F. for 24 hours; to a lesser extent on limes exposed to 70° or 105° to 110°; and not at all on comparable limes held at 50°. During the season when limes were not mature or stylar-end breakdown was not prevalent, heat treatments had little or no effect on the incidence of breakdown. (MQ 2-40)

6. Postharvest Diseases of Tropical Fruits. This P.L. 480 project in India showed good progress on isolation and identification of the pathogens involved in the diseases affecting mangos, guavas, bananas, litchis, papayas, and pomegranates during the marketing period. Progress was also made on sources of infection, particularly as related to diseases of field origin which carry over into the marketing period. (A7-AMS-6(k))

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Objective Measurement of Quality

Harding, P. L. and Sunday, M. B. 1964. Forecasting Quality and Pounds-Solids in Florida Oranges. USDA, AMS 533. (MQ 3-20)

Hatton, T. T., Harding, P. L., Reeder, W. F., Yeatman, J. N. and Krome, W.H. 1963. Fruit Weights and Corresponding Diameters for Florida Avocados. USDA, AMS 515. (BS 3-44)

Hatton, T. T., Harding, P. L., and Reeder, W. F. 1964. Seasonal Changes in Florida Avocados. USDA, Tech. Bul. 1310. (BS 3-44)

Quality Maintenance During Storage

Rygg, G. L. 1963. Experimental Storage of Dates in Bulk Bins. Date Growers' Inst. Rept. 40:8-9. (BS 2-54)

Harding, P. L., MacRill, J. R., Smoot, J. J. and Chace, W. G. 1964. Citrus Fruit and Bananas. ASHRAE Applications Data Book Chapter 52, pp. 621-634. (MQ 2)

Quality Maintenance During Transportation

Bennett, A. H., Chace, W. G., Jr., and Cubbedge, R. H. 1964. Thermal Conductivity of Valencia Orange and Marsh Grapefruit Rind and Juice Vesicles. Jour. Amer. Soc. of Heating, Refrigeration and Air Conditioning Engineering, pp. 76-77. (MQ 2-53)

Postharvest Disease Control

Smoot, J. J., and Melvin, C. F. 1963. Hot Water as a Control for Decay of Oranges. Proc. Florida State Hort. Soc. 76:322-327. (MQ 2-65)

Rygg, G. L., Wells, A. W., Norman, Shirley M. and Atrops, E. P. 1964. Biphenyl Control of Citrus Spoilage. Influence of Time, Temperature, and Carton Venting. USDA, Marketing Research Report 646. (MQ 2-28)

- Smoot, John J. and Segall, R. H. 1963. Hot Water as a Postharvest Control of Mango Anthracnose. Plant Disease Reporter 47(8):739-742. (MQ 2-68)
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- Hatton, T. T., Wolfenbarger, D. O., and Reeder, W. F. 1963. Postharvest Effects of Dipping and Fumigating Florida Avocados with Ethylene Dibromide and Ethylene Chlorobromide. Proc. Fla. State Hort. Soc. 76:355-360. (MQ 2-46)
- Ghosh, A. K., Tandon, R. M., Bilgrami and Srivastava, M. P. 1964. Studies on Fungal Diseases of some Tropical Fruits II. Post Infection Changes in the Sugar Contents of some Fruits. Phytopathologische Zeitschrift 50(3):283-288. (A7-AMS-6(k))
- Srivastava, M. P., Tandon, R. M., Bilgrami, K. S. and Ghosh, A. K. 1964. Studies on Fungal Diseases of some Tropical Fruits I. A List of the Fungi Isolated from Fruits and Fruit Trees. Phytopathologische Zeitschrift 50(3):250-261. (A7-AMS-6(k))

TRANSPORTATION AND MARKETING FACILITIES

Transportation and Facilities Research Division, ARS

Problem. Returns to producers and prices paid by consumers for horticultural crops are adversely affected by the use of inefficient marketing facilities, equipment, and methods. Better work methods, techniques, devices, operating procedures, equipment, and facility designs are needed for precooling, conditioning, storing, handling, cleaning, washing, waxing, sorting, sizing and packing potatoes, citrus fruits, deciduous fruits, vegetables, and other horticultural crops. Such improvements are needed at both shipping points and terminal markets. They would increase the productivity of labor, prolong the storage life of the commodities, reduce bruises and injuries to these products, reduce marketing costs, expand consumption, and reflect greater returns to producers.

It costs about 8 billion dollars a year to package food products, but without shipping containers and various other types of packages it would be impossible to move farm products efficiently from the widely dispersed areas of production through our complex marketing system to millions of consumers. New or improved packages and containers must be developed and evaluated to do this job more effectively. Continuing changes characterize the American marketing system. In protecting, distributing and selling perishable agricultural commodities, packages and containers must respond to a number of marketing system changes. The job of the research program in this area is to see that packages and containers keep pace with changes in the marketing system and reduce the cost of handling, transporting and storing agricultural commodities. It also seeks to improve service to consumers, promote greater sales of farm products, and increase the income of producers.

The cost of transporting farm products to market in 1963 was 5 billion dollars. Cost of transporting supplies used in farm production totaled more than one billion dollars. Further, costs of other marketing and production functions, such as loading and unloading vehicles, packaging storage and processing, also are affected by the efficiency of transport. These costs are important to the American farmer because they influence the return he receives from the sale of his products. They also are important to the American consumer because they influence the price he pays for his food. Therefore, the prosperity and efficiency of our entire agricultural industry and the economic well-being of the American consumer are closely tied to the efficiency of our transport system.

USDA AND COOPERATIVE PROGRAM

This is a continuing long-range research program covering the development of improved work methods, techniques, devices, operating procedures, equipment, and facility designs for precooling, conditioning, storing, handling, cleaning, washing, waxing, sorting, sizing and packing citrus fruits. Citrus fruit research is carried on by field offices at Gainesville, Fla., and Athens, Ga., in cooperation with the Florida Agricultural

Experiment Station, the Agricultural Engineering Research Division, the Market Quality Research Division, and commercial packers. The Federal professional man-years involved were 2.4 for F.Y. 1964.

Work on consumer packages and shipping containers is a continuing program of applied research conducted by marketing specialists, industrial engineers, and agricultural economists to (1) develop new or improved consumer packages, master containers, packing materials, and shipping containers for agricultural products; (2) evaluate them from the standpoint of cost of materials and direct labor to pack, and their ability to reduce product damage and increase product salability; (3) determine at which point in the marketing system packaging can be done most effectively; (4) improve the efficiency of packaging methods to cut costs; (5) and investigate the needs for and benefits of container standardization and simplification. The program is carried on in cooperation with experiment stations and industry in Florida and at the branch field station in Orlando, Florida, in other main producing areas, and in the principal terminal markets. The Federal professional man-years involved were 0.1 in F.Y. 1964.

The economic-engineering research in this field is a long-range program. It seeks to develop improved transport facilities, equipment and techniques and more efficient ways of using them in transporting agricultural products and supplies. It is interdisciplinary in nature, drawing upon the training and experience of economists, mechanical and industrial engineers, marketing specialists and various other scientists. All the work is done with the cooperation of transport firms, transport and refrigeration equipment manufacturers and lessors, trade associations, State universities and experiment stations. Field studies are carried out throughout the U. S. and on overseas shipments. Only one field station, Orlando, Florida, is permanently maintained to support this research program. Part of the work is accomplished through research contracts and cooperative agreements.

At the present time work is underway in each of the following fields:

(1) transport equipment, (2) refrigeration equipment and techniques, (3) better utilization of transport equipment and techniques, (4) loading methods, including unitized loading, (5) development and evaluation of pallet containers, and (6) overseas transport. The Federal professional man-years involved were 3.0 in F.Y. 1964.

PROGRAM OF STATE EXPERIMENT STATIONS

Research concerned with the economics of marketing at the State Agricultural Experiment Stations is reported under the appropriate areas of work of the Multiple Use Report, Marketing Economics Division. Likewise, research dealing with facilities and transportation conducted by the agricultural engineers at the State Experiment Stations is reported in the Multiple Use Report of the Agricultural Engineering Division, Areas 4,5, and 9. Related research in food science and technology is reported in the Multiple Use Report of the Utilization Research and Development Divisions.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Handling, Degreening, and Packing Citrus Fruit

This research, at Gainesville, Fla., is directed toward developing improved methods, devices, equipment, and facilities for conditioning, handling, and packing citrus fruits at Florida shipping points.

Three degreening test runs were made during the season on the early crop varieties of oranges, which are degreened from October through December. For each test the fruit was separated into the following color classifications: (1) Dark-green; (2) medium-color; (3) light-color; and (4) unsorted; which was taken at random from field-run fruit and used as a check. Degreening period was 84 hours, and fruit color was rated at 12-hour intervals except for the unsorted group which was color rated only before and after degreening. Color classifications were visual and all were made by the same person, using color plates as a guide. Based on the color rating of the fruit in the check lot before degreening, and the performance of fruit of the same color ratings in the dark-, medium-, and light-color lots during degreening, it was estimated that over 75 percent of the fruit in the unsorted check lot would reach passing color in about 48 hours. Therefore, the equivalent degreening time per box of this fruit need only be 57 hours. Based on an 84-hour standard versus a 57-hour degreening period and presorting for color, the time required in the degreening room for the majority of fruit could be lowered by 32 percent. This reduction in degreening time could increase the capacity of degreening facilities by 45 percent, which could amount to over 4 million 90-pound box equivalents a year during the October to January marketing period.

Additional data and information were obtained on complete commercial-scale pallet box handling systems; including labor and equipment inputs for fork-lift truck and box dumping operations at the packing plant and for grove operations; the latter in cooperation with personnel of the Agricultural Engineering Research Division. Comparative injury data on tangerines handled in pallet boxes and in conventional field boxes were obtained through cooperation of personnel of the Citrus Experiment Station. The entire effort was directed toward completing and publishing a final report to supersede Marketing Research Report No. 529, "Handling Florida Oranges in Pallet Boxes," which was published as an interim report, April 1962.

In the work on tangerine injuries, two tests were conducted to obtain further information on injuries to tangerines handled in full depth pallet boxes. Results showed no more decay for tangerines in pallet boxes than in conventional field boxes.

Process charts were prepared for the field-box system, pallet-box system, full-bulk system, and a modified full-bulk system. Summaries of these charts were made, providing comparative information on the number of operations, transportations, storages, and delays involved in each system. Approximately 900 feet of 16 mm. color movie film was shot of these systems to produce a motion picture which will show and compare the field-box system and newer systems of handling fresh citrus from the picking area to the packing line.

Data on weights of packed 4/5-bushel cartons of grapefruit were obtained from commercial packinghouses to: (1) Gain information on filled container weight versus dimension sizing from containers as commercially packed; and (2) compare computed container weights involving use of volumes with actual container weights. Each fruit was measured for polar and equatorial diameter using approved calipers. Specific gravity determinations were made of samples of fruit from each carton through cooperation of the Lake Alfred Citrus Experiment Station. Measurements of the fruit in each carton were averaged and volume determined by means of tables. Using the volume and the specific gravity values, theoretical carton weights were computed and compared with the actual weights.

The actual packed carton weights were all less than the computed carton weights in amounts ranging from two to eight percent. These preliminary data indicate some of the problems involved in the possible use of weight-fill in lieu of count-fill of shipping containers; including the effect of variability in specific gravity and fruit shape.

B. Cooling Citrus Fruits

Hydrocooling; the most widely used method for rapidly removing the field or harvest heat of such commodities as peaches, sweet corn, and citrus fruits; presents certain problems--particularly in the case of citrus--where detrimental physiological effects sometimes result. Existing methods of hydrocooling are also cumbersome and inefficient. Research conducted at Orlando and Gainesville, Fla., is designed to develop improved methods, equipment, operating practices, and techniques for use in existing or new facilities for more efficient precooling of fruits and vegetables.

Precooling studies of oranges in a wind tunnel revealed that considerable variation in surface temperature exists, depending upon location on the fruit with respect to direction of airflow.

Laboratory studies to determine the basic heat transfer characteristics and their relation to moisture content of Hamlin and Valencia oranges and Marsh grapefruit were continued at Orlando. Test results show a correlation between moisture content and thermal conductivity. Results of this work will make possible more efficient designs of precooling systems and eliminate the need for much of the costly "trial and error" type of applied research. A technical paper giving the procedure and findings of some of this work was presented at the Annual Meeting of American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Cleveland, Ohio, June 29, 1964.

The pilot-scale forced-air precooler chamber at Gainesville, was used to continue precooling research on citrus fruit. Using an initial air temperature of 15° F., precooling time of 60 minutes, and volume of airflow ranges of 2,980 to 7,410 c.f.m. in test runs of oranges, 3,180 to 8,040 c.f.m. for grapefruit, and 2,870 to 8,040 c.f.m. for tangelos, some of the findings are as follows: Loss of moisture per test run was 0.6 to 0.8 percent; conse-

quently, evaporative cooling was not an influencing factor. Reduction in temperature during test runs was 35.7° to 49.4° F. for oranges, 33.1° to 47.7° F. for grapefruit, and 34.7° to 54.7° F. for tangelos. Cooling was found to be markedly faster with initial fruit temperatures of 80° to 90° F. than with about 70° F. Cooling coefficients ranged from 2.48° to 5.48° F. per (°F.) and were inversely correlated with fruit size. Surface convective coefficients of heat transfer varied from 7.14 to 15.26 Btu per hr. (sq.ft.) (°F.). Theoretical heat removal ranged from 35.7 to 74.0 Btu per lb. in test runs of oranges, 31.1 to 55.5 Btu per lb. for grapefruit, and 33.9 to 76.4 Btu per lb. for tangelos. Corresponding experimental heat removal was 28.4 to 40.8 Btu per pound for oranges, 24.3 to 40.5 for grapefruit, and 28.9 to 45.7 for tangelos.

For the mass-average temperature data, 36 test runs were made with 500-lb. lots of Hamlin oranges, Marsh and Foster grapefruit, and Orlando tangelos. Fruit was cooled for 1.0 to 1.5 hrs. under a variety of test conditions. Initial air temperature was 15° F. Fruit temperatures were sensed with surface thermocouples and multipoint thermal probes inserted through the stylar end (polar) or the largest radius (equatorial). Temperature data from over 10,000 observations with corresponding time and distance along the radius values were transformed into normalized form for analysis as third-degree-polynomial multiple regression equations. Total correlation coefficients ranged from 0.97411 to 0.99917 among 216 individual equations and from 0.93454 to 0.98160 among equations of grouped data. Average location of the mass-average point was 0.7856 for oranges, 0.7722 for grapefruit, and 0.7953 for tangelos (where, 0.0 = center of the fruit and 1.0 = surface of the fruit). Approach of internal temperature distribution to apparent linearity was influenced by fruit characteristics, such as size and shape, as well as heat transfer from fruit surfaces or along the probes. A study of temperature distribution showed that a temperature representative of an entire fruit could be obtained only at the mass-average point.

C. Handling and Packing Fruits and Vegetables on Terminal Markets

1. Tiering Devices and Equipment. This research by the Hyattsville office was directed toward reducing the cost of storing fruits and vegetables at the wholesale level by increasing the utilization of available storage space in wholesale fruit and vegetable warehouses. During the report year work in this area was confined to the editing and publication of Marketing Research Report No. 622, "Storing Fruits and Vegetables on Pallets in Wholesale Warehouses."

2. Loading Out Delivery Trucks. The purpose of this research was to evaluate and compare the relative efficiency of selected methods and types of materials handling equipment for order assembly and truckloading used by wholesale distributors of fresh fruits and vegetables supplying both affiliated and non-affiliated retail stores so as to reduce unit costs and minimize spoilage and waste. The research was cooperative with the Wholesaling and Retailing Research Branch. During the report period work in this area was confined to the editing and publication of Marketing Research Report No. 665, "Three Methods for Loading Out Produce in Warehouses."

D. Consumer Packages and Shipping Containers

Exploratory work on developing consumer-size packages for citrus fruits continued in cooperation with Florida growers and shippers. Limes, oranges, and tangerines were test-packaged in various types of consumer trays constructed from molded pulpboard and plastic materials in combination with transparent plastic. Preliminary test shipments of tangerines packaged in pulpboard tills overwrapped with a transparent film received favorable trade reaction at both receiver and retail levels.

E. Transport Equipment

1. Thermal Rating of Refrigerated Trucks. This research is being conducted in cooperation with the National Bureau of Standards at the NBS facility in Washington, D. C. Its purpose is to develop a standard rating method to measure the thermal efficiency of refrigerated delivery truck bodies under conditions of 100° F. ambient, 50 percent ambient humidity, and 0° F. interior temperature.

Work was continued on the measurement of the rates of air exchange and the effect on load cooling caused by opening the door of a refrigerated truck. Preliminary tests were made using thermocouples, heat flow meters, and rapid response air flow probes designed and constructed at NBS. These instruments are used in conjunction with metered liquid nitrogen to maintain the steady-state interior temperature prior to the door opening and to restore the temperature immediately after the door is closed. Nitrogen from a self-pressurizing Dewar container is admitted to the interior through solenoid valves controlled by an air temperature multiple thermocouple grid. The heat load caused by the door opening can be determined by measuring the nitrogen required in excess of that required to maintain the steady-state temperature difference.

It is now anticipated that a final report will be issued during the next year.

2. Air Circulation in Refrigerated Trailers. The purpose of this research is to determine the most practical system for circulating cold air to obtain uniform temperature throughout a trailer load of frozen food. Previous tests have shown that temperatures at the front of a trailer near the cooling coils can be at 0° F. while other locations in the load may be several degrees above zero. This study seeks to find the best combination of blowers, air ducts, floor racks, and wall spacers to eliminate areas of high temperature. This is a cooperative program with the National Bureau of Standards being conducted at the NBS facility in Washington, D. C.

Work during the reporting period was devoted to analysis and reduction of the large amount of data obtained from previous trailer tests. Preliminary analysis of the tests comparing continuous and cyclic blower operation indicated somewhat greater load temperature changes during refrigeration "off" periods under the 12° F. thermostat differential, compared to 4° F.

and 6° F. when the blower was operated continuously. The thermostat sensing element was located in the return air stream near the evaporator coils and behind a bulkhead near the front of the trailer. The space forward of the bulkhead warmed faster than the cargo space when the blower was cycled off. With the blower under constant operation under the refrigeration "off" cycle, the forward space warmed more slowly, at approximately the same rate as the cargo space.

The 12° F. thermostat differential produced exposed cargo surface temperature changes of about 10° F. when the blower was cycled and about 8° F. when the blower operated continuously. Center cargo temperatures changed about 0.5° F. in each case. All tests were conducted with ambient temperatures of 100° F. and mean interior (return air) temperature of 0° F.

3. Liquid Nitrogen Refrigeration for Frozen Food Trailers. The objective of this study is to determine whether it is practical to use liquid nitrogen as a refrigerant in vehicles transporting frozen foods. Previous research has shown that liquid nitrogen and liquid carbon dioxide will provide 0° F. temperature for frozen foods. However, analysis shows that these expendable refrigerants are more costly than conventional mechanical systems. This project is being discontinued until costs of expendable refrigerants are reduced sufficiently to make their use economically feasible.

4. Multi-Purpose Transport Vehicles. Van Containers--A design concept for a multi-purpose van container was developed during the year. It was described in a press release which generated widespread interest among steamship lines, railroads, freight forwarders, trucking groups, transport and refrigeration equipment manufacturers. Meetings were held with representatives of these groups and several offered to make available their facilities and technical assistance in engineering, construction and testing of the prototype van. An application for public-use patent on the van is now being processed.

The container can be used to haul both frozen and nonfrozen perishable products and nonrefrigerated cargo. It also can be used to carry freight by rail piggyback, highway, water (fishyback), and perhaps by air in moving farm products to the consumers.

Trailers--Research was begun late in the year to develop practical, low cost, conversion systems by which conventional refrigerated trailers and dry cargo vans can be made dual-purpose vehicles for use in transporting bulk as well as packaged cargo. It is being carried out under a cooperative agreement with the Oregon Agricultural Experiment Station. Several trailers equipped with prototype conversion systems are now being tested in cooperation with several trucking firms in the Pacific Northwest. Initial results indicate that the rates of vehicle utilization are materially increased when the conversion systems are used. However, the project has not progressed far enough to obtain adequate data on vehicle utilization rates, operating costs, and revenue yields.

5. Improved Ventilated Piggyback Trailers. Research to develop improvements in rail piggyback trailers which will facilitate better product ventilation was continued during the year. Previous work showed that conventional highway trailers used for this service did not provide a flow of outside air through loads of perishables sufficient for adequate cooling.

Several trailers incorporating new ventilation systems were tested with shipments of watermelons from Florida to northern markets. One type van tested was equipped with adjustable scoops on the front ventilation doors to direct air into the van when hauled rear-end-forward on rail piggyback flat cars. Another type studied had under-floor scoops to direct air into the cargo area where the ram-effect forced it upward through the load and out the exhaust ports in the upper sidewalls of the van. The latter type trailer gave the best results. In paired tests the temperature of watermelons in a conventional van rose three degrees during transport while those shipped in the van with under-the-floor air scoops cooled 15 degrees. Additional work to develop further refinements in this system and to develop and test new equipment is being continued.

F. Transport Techniques

1. Pallet Containers for Transportation. All field work has been completed, the data analyzed and results evaluated on rail and truck shipments of apples in both expendable and reusable pallet containers of several different types. The initial report was extensively revised during the year. It is now being reviewed.

This research has shown that savings from using pallet containers of about 900 pounds capacity as compared to conventional 40 pound corrugated boxes range from 0.1 cents per pound, or about \$150.00 per carload for one trip to 0.2 cents, or approximately \$300.00 per car when the pallet containers are used for two trips. For some types of pallet containers greater savings may be made by using them for three or more trips. The economies in pallet container usage in transport result from lower container, packing, handling, freight and protective service costs per pound of fruit.

2. Loading Patterns for Fiberboard Citrus Boxes. A modified bonded-block stacking pattern for corrugated fiberboard boxes was developed and has been tested for three shipping seasons. The pattern provides inter-connecting channels throughout the load to allow air circulation to each box of fruit. Air circulation through the new load was improved in both ventilated and refrigerated shipments. Product temperatures were maintained nearer the recommended levels during transportation. The new pattern is easy to load and is adaptable to any size trailer. Good row and stack alignment are maintained during transport and commodity and container damage are held to a minimum. It is estimated that more than 90 percent of all Florida oranges and grapefruit packed in the 4/5-bushel corrugated box are stacked in this way for transport by truck and rail piggyback.

A report on this research has been submitted for publication. This project will be discontinued.

3. Unitized and Palletized Transport. A literature review of systems analysis and operations research applications to the handling and transporting of agricultural commodities was completed during the year. This information has been used to plan work in which this research technique will be used to evaluate different methods of unitized and palletized transport.

Observations were made of the operations of handlers and shippers of carrots in California, Arizona, and Texas to determine the feasibility of applying systems analysis and operations research techniques to improve transport and handling of this product. Data developed in this survey have been used to construct a "word model." This model may serve as the basis for constructing a mathematical model which can be used to predict the results of changes in any part of the transport system for a particular product.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Handling, Degreening, and Packing Citrus Fruits

Grunig, James E. 1963. Bagging Citrus Fruit. Agricultural Marketing, Vol. 8, No. 10, October 1963, p. 6.

Cooling Citrus Fruits

Bennett, A. H., Chace, W. G., Jr., and Cubbedge, R. H. 1964. Thermal Conductivity of Valencia Oranges and Marsh Grapefruit Rind and Juice Vesicles. Paper presented at the 71st Annual Meeting, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Cleveland, Ohio, June 29-July 1, 1963.

Soule, James, Yost, G. E., and Bennett, A. H. 1964. Certain Heat Characteristics of Oranges, Grapefruit, and Tangelos During Forced-Air Precooling. Paper at the Annual Meeting, American Society of Agricultural Engineers, Fort Collins, Colo., June 21-24, 1964.

Handling and Packing Fruits and Vegetables on Terminal Markets

Ferris, Richard T. 1964. Storing Fruits and Vegetables on Pallets in Wholesale Warehouses. Marketing Research Report No. 622, February 1964, 38 pp.

Lundquist, Arnold L. and Bouma, John C. 1964. Three Methods for Loading Out Produce in Warehouses. Marketing Research Report No. 665, June 1964, 44 pp.

Lundquist, Arnold L. 1964. Is Your Loading Out Method Efficient? Agricultural Marketing, Vol. 9, No. 7, July 1964, pp. 4 and 5.

1964. More Efficient Produce Warehouses. Agricultural Marketing, Vol. 9, No. 6, June 1964, pp. 6 and 7.

Transport Equipment

Guilfooy, R. F., 1963. Liquid Carbon Dioxide Refrigeration in a Frozen Food Trailer. November 1963. AMS-522. pp. 15.

Clayton, J. E., 1964. USDA Transport Research--Past and Future. Paper presented at the National Conference on Handling Perishable Agricultural Commodities, Purdue University. March 1964.

Guilfooy, R. F., 1964. Transport of Perishable Foods. Paper presented at the Annual Food Engineering Conference, Michigan State University. April 1964.

Transport Techniques

Press release, 1964. New Van Container Concept Developed by USDA. June 1964.

COOPERATIVE MARKETING
Marketing Division, FCS

Problem: Farmers are expanding their use of cooperative marketing. There are constant changes in transportation, processing, and distribution technology, and in market organization and practices, and changes on the farm itself. In view of these developments, farmer cooperatives and other marketing firms require research results to perform both efficiently and effectively. Such research can assist farmers to maintain and strengthen their bargaining power, increase efficiency, and meet the quality, quantity, and service needs of today's food and fiber marketplace.

Cooperative marketing is a major way for farmers to get maximum returns from their products in the current and rapidly changing market. Farmers own and control cooperatives specifically to increase their income from crops and livestock. Gains are not automatic, however. Cooperatives must plan, develop, and actually manage the specific marketing program and services that will yield the most for their members. Marketing cooperatives must know what the market demands. They must be able to compute the probable cost of different ways of serving the market. They must understand the possibility of major economies in a well coordinated joint sales program, and understand the methods and potentials of bargaining. Management must achieve minimum costs through improved organization, good use of existing plant and personnel, and the selection and use of new equipment and methods.

USDA AND COOPERATIVE PROGRAM

The Department conducts a continuing long-range program of basic and applied research and technical assistance on problems of marketing farm products cooperatively. Studies are made on the organization, operation, and role of farmer cooperatives in marketing. While most of the research is done directly with cooperatives, the results are generally of benefit to other marketing firms. The work is centered in Washington, D.C. Many of the studies, however, are done in cooperation with various State experiment stations, extension services, and departments of agriculture.

Federal professional man-years devoted to research in this area totaled 23.3, of which 1.0 was devoted to cooperative marketing of citrus.

Research also is conducted under contract with land-grant colleges, universities, cooperatives, and private research organizations. During the period of this report, contract research was performed by universities and colleges in Florida, Iowa, Louisiana, Montana, North Dakota, and West Virginia, and by one private research company.

PROGRAM OF STATE EXPERIMENT STATIONS

The State stations maintain a very broad research program in commodity marketing, the findings of which are valuable to cooperatives and to other marketing firms. There are at this time nine projects in eight States that deal specifically with cooperative marketing. Five projects are commodity oriented and deal with grain, tobacco, milk, livestock, and fruits and vegetables. These projects seek to find out how cooperatives are adjusting or might better adjust to changes in market structure and marketing practices. In some instances researchers are studying the success and failure of cooperatives and the organizational structure. One study of the history of major cooperative marketing associations in the State will be published as a book and will undoubtedly receive nationwide attention.

Because of the growing interest in the role of cooperatives in market structure, one State recently initiated a major project in this area. The project leader views cooperative enterprises as a structural dimension of farm markets. The objectives and operating procedures of cooperatives will be studied to see if they have a unique impact upon market conduct and performance. If so, this may have significant implications for Government policies and programs.

The total research effort on cooperative marketing in the eight States is 3.4 professional man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Improving Cooperative Sales and Distribution Methods

To provide growers and shippers with guidelines that will help them to adapt to changing marketing conditions, analysis is underway to determine the nature of large-scale buyers' requirements for Florida fresh citrus. The nature and extent of specification buying is being studied in detail.

B. Potentials in Cooperative Marketing

Study continued on the present status and trends in cooperative marketing of these products. Research will include evaluation of the potential of cooperatives for increasing their operating efficiency and market effectiveness through integration, coordination, consolidation, expansion, or other means.

C. Pooling and Pricing

Research is underway to determine the impact of the 1962 freeze on various types of pooling arrangements used in the Florida citrus industry. Information will be provided marketing organizations on the advisability and means of adjusting conventional pooling arrangements to emergency situations. This work is being done under contract with the University of Florida.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Hulse, F. E. 1964. Co-op Participation Plans Help Market Florida
Citrus. News for Farmer Cooperatives (Mar.).

ECONOMICS OF MARKETING
Marketing Economics Division, ERS

Problem. Most agricultural industries are experiencing rapid and drastic changes in their market organization and practices. These changes are affecting both farmers and consumers. Research is needed to keep abreast of such changes and to indicate their probable consequences. There have been substantial advances in recent years in increasing efficiency and reducing costs through adoption of new technology in producing, assembling, processing, and distributing farm products. However, for producers and marketing firms to remain competitive, additional information is needed on margins, costs, economics of scale and efficiencies possible in the marketing of farm products.

Marketing research also is increasingly concerned with evaluating present and prospective programs pertaining to agriculture, such as the Food Stamp Program and Federal Grading Activities and to the changing structure of market industries as this may influence the bargaining power of farmers. Research also is being directed to the economics of transportation and storage activities of both private firms and government. Increasing attention is being given to the longer-term outlook for various products and markets as an aid in better assessing the prospects for increasing industrial employment under the Rural Development Program and in assessing prospective interregional shifts in the areas of production and marketing for specific products.

USDA AND COOPERATIVE PROGRAM

The Department conducts a continuing program involving a series of studies to show: (1) Detailed analyses of marketing costs and margins in the various stages and channels in handling, processing, transporting, and distributing horticultural and special crops and related products; (2) comparative efficiency and costs of present agencies, organizations, methods, and practices in performing the services involved at each important stage in taking the crop products from farms to final users; and (3) the influences on costs and efficiency of such factors as grades and standards, methods of determining and maintaining product quality, and governmental regulatory and informational programs. On the basis of results of such studies, recommendations are made on possible means of increasing the efficiency of marketing, or increasing returns to growers, and of providing consumers with the choices they desire.

The Federal scientific effort devoted to this research in F.Y. 1964 amounted to 7.6 professional man-years on citrus and subtropical fruit.

PROGRAM OF STATE EXPERIMENT STATIONS

Research on citrus and subtropical fruit is carried out by the State agricultural experiment stations located in areas of warm winter climates. The research is not concentrated heavily in any one functional area. One station has a project on marketing practices and prices, another a project on the characteristics of the market and consumer demand, another one on the costs of various methods of harvesting, assembly and packing, and trends in costs of processing. One station has a project on testing for determining market potential for a new product. A total of 2.8 professional man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Structures, Practices and Competition

1. The Lower Rio Grande Valley fruit and vegetable market is being studied. Particular attention has been given to prices received by growers for tomatoes and citrus. The Valley tomato market appears to operate in a highly competitive manner. As a result of this project there is a better understanding of the relations between grower and f.o.b. prices and of marketing margins at shipping point and costs of assembling, handling, and packing. Growers seem willing to do more culling of tomatoes in the field. Similar analyses of prices are underway for citrus, carrots, and onions.

2. Changes in the structure of California fruit and vegetable markets are affected by transportation methods. A study of agricultural exemption, competition, and efficiency in the motor carrier industry disclosed that fruits and vegetables are the most important out-flow of exempt commodities originating in California. They accounted for 33 percent of the 1961 tonnage of agricultural commodities transported across the California border and for 45 percent of the total ton miles. Trucks hauled about 30 percent of out-bound fruit and vegetable shipments. Further research is being done on the probable effects of two alternative transportation policies--the elimination of agricultural exemption, or the extension of agricultural exemption to other modes of transportation.

3. Any attempt at a revenue maximizing program for the citrus industry requires a precise knowledge of the demand functions for each component of the total citrus market. Data concerned with the determination of an aggregate demand function for frozen orange concentrate, the degree of substitution among 3 major classes of orange concentrate and the position of orange concentrate in relation to other concentrated, canned and chilled citrus juices are being analyzed.

B. Merchandising and Promotion

1. Effect of Packaging on Sales of Fresh Grapefruit. Tests conducted in a sample of supermarkets in the Paterson, New Jersey, area indicate that packaging grapefruit in consumer size units significantly increased the sales of fresh grapefruit. Compared with test fruit (size 96) offered loose or in bulk displays, sales increased 63 percent when grapefruit was offered in

grower labeled polyethylene bags. A 28 percent increase was obtained by offering the grapefruit in plain unlabeled polyethylene bags and a 38 percent increase was realized when both unlabeled bagged fruit and loose fruit were offered from a combination display. All packages contained 6 fruit and both packaged and loose fruit were offered at the same multi-unit (6 fruit) price. Indian River pink grapefruit was used in all tests.

2. Effect of Promotion on Sales of Frozen Concentrated Orange Juice and Returns to Producers. An analysis of the sales response and effectiveness of the 1959 special promotional campaign for frozen concentrated orange juice has been completed and the findings published. Additional data on changes in advertising expenditures during this period by all segments of the industry are now being analyzed and related to shifts in demand during the 1959 promotion. Effects of the total promotional effort on grower returns are being estimated. Preliminary findings indicate that the 13 percent increase in demand for frozen concentrated orange juice in 1959-60 as compared with 1958-59, was accompanied by a threefold increase in total advertising expenditures for the product. However, the estimated dollar returns to citrus industry was about three times as great as the increase in advertising expenditures. Other findings indicate an increase in grower returns of 25 to 30 cents per box as a result of increased promotion. This work is nearing completion and a report will be issued in early 1965.

An evaluation of the 1962 special promotion campaign for frozen concentrated juice has been completed. Findings indicate 2.5 million more gallons of juice were sold in September through mid-December 1962 as a result of the promotion. It is estimated that a reduction in retail price of 3 cents per 6-ounce can would have been required to move the same volume of juice into consumption. Such a price drop would have reduced retail revenues approximately \$16.8 as compared to the promotion campaign cost of \$3.5 million. Because of the severe freeze that occurred in Florida on December 12 and 13, 1962, it was not possible to appraise the influence of the campaign beyond December 15, 1962.

3. Consumer Purchases of Citrus, Citrus Products, and Other Products. On a monthly basis, only about 20 percent of the Nation's families have bought frozen concentrated orange juice during the 1963-64 crop year, about the same as in 1950-51. From 1954 to 1962 the proportion buying was close to 30 percent. The proportion of families buying canned orange juice dropped from around 15 percent per month in 1950-51 to 4 percent in 1963-64, and the proportion buying canned grapefruit juice was down from 10 to less than 5 percent. In like manner, the proportion of families that buy fresh oranges and grapefruit also is well below levels that prevailed in the early 1950's. Prices paid for frozen concentrated orange juice were record high in 1963-64, but, even so, consumer expenditures were down from the 4 preceding years. Expenditures for other canned citrus juices also were down despite higher prices. On the other hand, consumers are buying canned fruit drinks in increasing volume. Purchases in the first half of 1963-64 were about equal to the amount bought in the entire 1959-60 season. Moreover, the use of canned fruit drinks now exceeds the use of frozen concentrated orange juice and is equal to the use of total canned juices. Use of frozen concentrated fruit drinks also is on the upturn. Indications are that recently introduced synthetic fruit drinks are gaining consumer acceptance.

4. Market Development for Desert Citrus. Work being conducted under cooperative agreement with the Arizona Agricultural Experiment Station is directed toward an evaluation of the potential of the desert citrus industry, identifying major marketing problems and appraising the effectiveness of alternative marketing techniques designed to promote the consumption of fresh citrus. Data for the desert grapefruit industry showing trends in acreage, number of bearing trees by variety, production, utilization and prices received have been developed and published. Data have been collected as a basis for projecting supply of desert citrus by type and variety through 1967. Local and regional markets for desert citrus are now being studied to delineate the characteristics of market outlets available and to determine promotion and merchandising practices of growers and shippers. Additional plans are being developed to evaluate alternative merchandising and promotional practices of producer groups marketing citrus in the area.

5. Long-Term Sales Effects of Advertising and Promotion for Florida Citrus. Analyses show definite upward shifts in the demand for oranges during selected periods from 1920-21 to 1960-61. Demand shifts for grapefruit were generally upward until the early 1950's when a downward trend began. Insufficient data are available to relate demand shifts to specific market factors and promotional investments and the work has been discontinued.

C. Margins, Costs and Efficiency

Marketing margins are calculated for lemons sold in 4 markets, California navel oranges sold in 3 markets, California Valencia oranges sold in 3 markets, and Florida oranges sold in 4 markets. In the period 1957-58 to 1961-62 the average farm-retail spread for lemons was 81 percent of the retail price and the grower's share was 19 percent. Stability was characteristic of lemon prices and spreads in all markets. The total margin in 1961-62 was 82 percent, one point higher than the 5 season average. The total marketing margin for oranges in the 6 seasons, 1956-57 to 1961-62, was 69 percent of their retail price, leaving an average of 31 percent for the growers. The margin in 1961-62 was slightly higher than the 6 season average--71 percent. The largest component was the retail margin. Over the 6 seasons it averaged 36 percent of the retail price.

D. Market Potentials

Market Potentials for Kona Coffee. Research continues in cooperation with the Hawaiian Experiment Station to help improve returns from Kona coffee, the producers of which face severe price problems stemming from the world coffee situation. Results of a limited market test of a new instant Kona coffee in Honolulu indicate the product met with high acceptance as a quality product. Thus, it is saleable in competition with other coffees. The key questions from a returns standpoint are: can a consistently high-quality distinctive coffee be supplied on a continuing basis, and what premium can be maintained over other coffees?

E. Transportation Costs and Services

1. Transportation of Fresh Fruits and Vegetables. This is a two-phase project dealing with interstate rail and highway transportation of California and Arizona fruits and vegetables and is concerned with the flow patterns and trends associated with rail and highway movement of fresh produce from California and Arizona to other States.

Striking changes have taken place in the use of highway and rail carrier service. Since 1951, the share of interstate traffic dispatched from California and Arizona shipping points by rail has dropped from 87 to 70 percent of total movement from those areas. The decrease has occurred primarily because shipments moving to points west of the Mississippi River --short and intermediate range hauls--have been tending to go more and more by truck. Trucks have increased their share of shorthaul traffic from 67 to 83 percent of the total and their proportion of intermediate range hauls from 20 to 66 percent. These shifts in shippers utilization of carriers reflect the motor carrier's ability to offer attractive rates and fast service. In many instances motortruck transportation has become so much more attractive than rail service that some users are willing to pay higher charges for truck service than they would have needed to pay for the nearest comparable rail service.

The second phase of this study, based on receiver interviews, is scheduled for completion by December 1964. Preliminary findings confirm those of the shipper survey. Receivers utilize rail and truck service to improve plant operations and to serve customers better.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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Manchester, Alden C. July 1964. The organization of wholesale fruit and vegetable markets in Chicago, Lincoln, Los Angeles, Louisville, Milwaukee, New Orleans, Oklahoma City, Omaha, San Francisco-Oakland, Tulsa, and Wichita. ERS-163. pp. 128.

ECONOMIC AND STATISTICAL ANALYSIS

Economic and Statistical Analysis Division, ERS

Problem. Because of the instability of the prices he receives and rapidly changing conditions of agricultural production, the farmer stands in special need of accurate appraisals of his economic prospects if he is to plan and carry out his production and marketing activities in an efficient and profitable way. The typical farmer cannot afford to collect and analyze all the statistical and economic information necessary for sound production and marketing decisions. It has long been a goal of the Department to provide the farmer with economic facts and interpretations comparable to those available to business and industry, through a continuous flow of current outlook information; the development of longer range projections of the economic prospects for the principal agricultural commodities; and analyses of the economic implications of existing and proposed programs affecting the principal farm commodities.

USDA AND COOPERATIVE PROGRAM

Commodity Situation and Outlook

The outlook and situation program provides continuous appraisal of the current and prospective economic situation of citrus fruits. Regular appraisals are supplemented by special analysis when needed. Results of these appraisals, findings of special analyses, and long-time series of basic data are published in the Fruit Situation, issued 4 times a year, and in brief reviews in quarterly issues of the National Food Situation and the Demand and Price Situation. A comprehensive analysis of the fruit and tree nut situation is presented at the Annual Outlook Conference. Presentations also are made at regional or State outlook meetings, meetings of farm organizations, and to various agricultural industry groups. Special studies are made to determine probable effect of proposed programs on supply, price, and consumption of fruits and tree nuts. Basic statistical series on stocks, foreign trade, consumption, and price are compiled, improved and maintained for general use in statistical and economic analysis. This work involves approximately .5 professional man-years in Washington, D. C.

PROGRAM OF STATE EXPERIMENT STATIONS

For the most part the States depend upon the U. S. Department of Agriculture for the yearly across-the-board commodity situation and outlook research. The State extension staff members supplement and adapt such research information to meet the commodity situation of their States.

Four States have projects that deal specifically with analysis of current price trends and prediction of future prices. There is increasing interest in longer range price prediction because of the growing specialization of farms, which make yearly enterprise shifts less common and less feasible, and which calls for large capital commitments over longer periods of time.

The total direct research effort in the situation and outlook area is approximately 1.7 professional man-years. While not designated as outlook research, much of the research conducted by the experiment stations and reported elsewhere contributes to improved understanding of price-making forces, which in turn improves market situation analysis and price forecasting.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

In recognition of the growing importance of processing as an outlet for fruit crops, the situation and outlook work in this area was strengthened.

A paper on U. S. fruit and vegetable trends and prospects was presented in March at the Sixth Annual Agricultural Marketing Conference at Ohio State University.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Pubols, B. H. Fruit Situation. Published quarterly. ERS, USDA, Washington, D. C.